UCRL-50027-97

Environmental Report 1997

California Red-Legged Frog
Rana aurora draytonii

Lawrence Livermore National Laboratory

Cover

The California red-legged frog (*Rana aurora draytonii*), a federally threatened species, established new populations at both the LLNL Livermore site and Site 300 in 1997. The California red-legged frog is the largest native frog in California, growing up to 138 mm, or more than 5 inches long. The original Calaveras jumping frog, it uses its strong legs to move long distances to find water during drought periods. At both LLNL sites its habitat is protected by use of project exclusion zones to protect breeding areas and by emplacement of shelter boxes. The editors thank wildlife photographers Liittschwager and Middleton for the use of their photograph.

Cover photograph: ©David Liittschwager & Susan Middleton 1996

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Environmental Report 1997

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September 1, 1998 **Lawrence Livermore National Laboratory**

UCRL-50027-97
Distribution Category UC-702

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1301 Clay Street
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SEP 1 5 1998

Distribution:

SUBJECT: 1997 Site Annual Environmental Report (SAER) for the Lawrence Livermore National Laboratory (LLNL)

This report, prepared by LLNL for the U.S. Department of Energy, Oakland Operations Office (DOE/OAK), provides a comprehensive summary of the environmental program activities at Lawrence Livermore National Laboratory (LLNL) for Calendar Year 1997. Site Annual Environmental Reports (SAERs) are prepared annually for all DOE sites with significant environmental activities, and distributed to relevant external regulatory agencies and other interested organizations or individuals.

To the best of my knowledge, this report accurately summarizes the results of the 1997 environmental monitoring, compliance, impacts assessment, and restoration program at LLNL. This assurance can be made based on DOE/OAK and LLNL review of the SAER, and quality assurance protocols applied to monitoring and data analyses at LLNL.

A reader survey form is provided with the SAER to provide comments or suggestions for future versions of the report. Your response is appreciated. Questions or comments regarding this report may also be made directly to DOE/OAK, by contacting Steve Black of the Environment, Safety, and Health Division at (510) 637-1595, or by mail to the address above.

Sincerely,

Henry DeGraca

Henry DeGraca, Acting Director
Livermore Operations Division

Preface

The *Environmental Report 1997* is prepared for the U.S. Department of Energy (DOE), as required by DOE Order 5400.1 and DOE Order 231.1, by the Environmental Protection Department (EPD) at the Lawrence Livermore National Laboratory (LLNL). The results of LLNL's environmental monitoring and compliance effort and an assessment of the impact of LLNL operations on the environment and the public are presented in this publication.

To produce a more readable and useful document for our diverse readership—including regulators, scientists and engineers, educators, the media, public interest groups, and interested citizens—we have, as in the past two years, divided this report into two volumes: a main volume and a Data Supplement.

The main volume describes LLNL's environmental impact and compliance activities and features descriptive and explanatory text, summary data tables, and plots showing data trends. The summary data include measures of the center of data, their spread or variability, and their extreme values. The main volume contains the Executive Summary and the Compliance Summary; it features individual chapters on monitoring of air, sewage, surface water, ground water, soil and sediment, vegetation and foodstuff, and environmental radiation; and it contains chapters on site overview, environmental program information, radiological dose assessment, and quality assurance. Information on both the Livermore site and Site 300 is presented in each chapter.

The Data Supplement (previously referred to as Volume 2) provides individual data points, where applicable, some summary data, and more detailed accounts of sample collection and analytical methods.

The main volume, which can be read without access to the Data Supplement, contains all information of interest to most of our readers. The main volume will be distributed as usual, but the Data Supplement will be sent only upon request; a card for this purpose is included on the last page of this volume. Both the main volume and the Data Supplement are available on the Internet at http://www.llnl.gov/saer.

As in our previous annual reports, data are presented in Système International (SI) units. In particular, the primary units we use for radiological results are becquerels and sieverts for activity and dose, respectively, with curies and rem used secondarily ($1\ Bq = 2.7 \times 10^{-11}\ Ci$; $1\ Sv = 100\ rem$). Units are discussed in Supplement 12-1 of Chapter 12, Radiological Dose Assessment, in the main volume.

Preface

This document is the responsibility of the Operations and Regulatory Affairs Division of EPD.

Monitoring data were obtained through the combined efforts of the Operations and Regulatory Affairs Division, Environmental Restoration Division, the Chemistry and Materials Science Environmental Services laboratories, and the Hazards Control Department of LLNL. Special recognition is deserved for the dedication and professionalism of the technicians who carried out environmental monitoring—Gary A. Bear, David J. Castro, Paul C. Dickinson, David L. Graves, Charles Hunt, Renee Needens, Terrance W. Poole, Donald G. Ramsey, Rebecca J. Ward, Rhonda L. Welsh, and Robert Williams—and to the data management personnel—Jennifer Clark, Kimberly A. Stanford, Louise Morris, Suzanne Chamberlain, and Connie Wells. Special thanks go to Judith L. Kelly for secretarial support and collation and distribution of drafts.

In addition, the following people made significant contributions to this report: Rita Ann Brösius, Janice Butler, Chris Choate, Brett Clark, MaryAnne R. Cox, Harry L. Galles, Everett B. Guthrie, Cynthia Herman, Joy Hirabayashi, Bryant Hudson, Albert L. Lamarre, Grace Massa, Patricia L. Ottesen, Ellen Raber, Duane W. Rueppel, Ann Ruth, Sterling R. Sawyer, Richard L. Shonfeld, Elizabeth L. Silva, Jeffrey Sketchley, Janet Tanaka, Maria Tornabene, and John Ziagos.

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Executive Summary

Robert J. Harrach
Howard L. Lentzner

Introduction

Lawrence Livermore National Laboratory (LLNL), a U.S. Department of Energy (DOE) facility operated by the University of California, serves as a national resource of scientific, technical, and engineering capabilities. The Laboratory's mission focuses on nuclear weapons and national security, and over the years has been broadened to include areas such as strategic defense, energy, the environment, biomedicine, technology transfer, the economy, and education. The Laboratory carries out this mission in compliance with local, state, and federal environmental regulatory requirements. It does so with the support of the Environmental Protection Department, which is responsible for environmental monitoring and analysis, hazardous waste management, environmental restoration, and assisting Laboratory organizations in ensuring compliance with environmental laws and regulations.

LLNL comprises two sites: the Livermore site and Site 300. The Livermore site occupies an area of 3.28 square kilometers on the eastern edge of Livermore, California. Site 300, LLNL's experimental testing site, is located 24 kilometers to the east in the Altamont Hills, and occupies an area of 30.3 square kilometers. Environmental monitoring activities are conducted at both sites as well as in surrounding areas.

This summary provides an overview of LLNL's environmental activities in 1997, including radiological and nonradiological surveillance, effluent, and compliance monitoring, remediation, assessment of radiological releases and doses, and determination of the impact of LLNL operations on the environment and public health.

Environmental Monitoring Results

During 1997, the Environmental Protection Department sampled air, sewerable water, ground water, surface water, soil and sediment, vegetation and foodstuff, and measured environmental radiation. Over 24,000 environmental samples were taken and results were obtained for more than 260,000 analytes.

LLNL's sampling networks undergo constant evaluation. Changes are made, as necessary, to ensure adequate and cost effective monitoring of all environmental media potentially affected by LLNL operations. Once samples are collected, they are analyzed for radioactive and nonradioactive substances using standard methods such as analytical procedures approved by the U.S. Environmental Protection Agency (EPA), special systems such as the continuous monitoring system for Livermore site sewage, or special analytical techniques designed to measure very low levels of radionuclides. Environmental radiation is also measured directly using dosimeters.

Air Monitoring

Air surveillance monitoring was performed for various airborne radionuclides (including particles and tritiated water vapor) and beryllium at locations on the Livermore site and Site 300, and at off-site locations throughout the Livermore Valley and Tracy area. Concentrations of all monitored radionuclides and beryllium at all of these locations were well below levels that would endanger the environment or public health, according to current regulatory standards. As examples: in 1997, the concentration of plutonium on air filter samples collected at LLNL on-site locations, perimeter locations, and Livermore Valley locations showed median values, respectively, of only 0.0064%, 0.0012%, and 0.0014% of the federal Derived Concentration Guide (DCG). The DCG specifies the concentration of radionuclides in air or water that could be inhaled or ingested continuously 365 days a year without exceeding the DOE radiation protection standard for the public. Median concentrations of tritiated water vapor at Livermore Valley sampling locations showed a highest median value of 0.002% of the DCG, while the highest median values on the Livermore site perimeter and within the site boundaries were, respectively, 0.007% and 0.1% of the DCG. The highest median concentration of beryllium on the Livermore site perimeter was 0.1% of the guideline level established by the Bay Area Air Quality Management District and the EPA. Similar results (small fractions of guideline levels) were found at air surveillance monitoring locations at Site 300 and its environs.

Effluent Monitoring

At the start of 1997, stack air effluent was monitored continuously for radionuclides at nine buildings on the Livermore site; by the end of the year this number was reduced to six buildings as operations changed. Presently monitored facilities are the Tritium Facility (Building 331), the Plutonium Facility (Building 332), the Heavy Element Facility (Building 251), and three buildings involved with Laser Isotope Separation program activities. Building 331 emissions accounted for 97% of the estimated total tritium emissions from the site in 1997; emissions from this facility remain at a level far below those of the 1980s. Radionuclide emissions from the other monitored facilities were very low. This data from stack effluent monitoring gives an accurate, time resolved measure of the quantity of radionuclides released from these major facilities, and provides realistic source terms to improve the quality and credibility of our air dispersion and dose assessment modeling.

Nonradioactive air emissions from exempt and permitted sources at LLNL were quite small and typical of values in previous years. For example, total emission of nitrogen oxides from the Livermore site in 1997 was about 59 kg/day, which is 0.012% of the quantity of this air pollutant released daily over the entire Bay Area; corresponding numbers for reactive organics are 37 kg/day and 0.007%. The total emission of criteria air pollutants (nitrogen oxides, sulfur oxides, particulate matter, carbon dioxide, and lead) is approximately 100 kg/day for the Livermore site and about 25 times smaller for Site 300.

Wastewater Monitoring

Discharges of radioactive and hazardous materials to the combined sanitary and industrial sewer at the Livermore site are controlled by limiting the disposal of those materials, implementing engineering controls, and routing some discharged material to retention tanks for later characterization and treatment. Flow-proportional samples of discharged wastewater are regularly collected and analyzed (for metals, radioactivity, toxic chemicals, and water-quality parameters) to assure that LLNL's sewage effluent meets the requirements of the permit granted by the City of Livermore. In addition, effluent is monitored continuously for pH, selected metals, and radioactivity. Should concentrations be detected above warning levels, an alarm sounds and LLNL's sewer diversion system is automatically activated. The diversion system captures all but the first few minutes of wastewater flow that causes an alarm, thereby protecting the Livermore Water Reclamation Plant (LWRP) and minimizing any required cleanup.

In 1997, the Livermore site discharged an average of 0.91 million liters per day of wastewater to the City of Livermore sewer system, an amount that constitutes 4.4% of the total flow to the system (about 20% of this flow was generated by Sandia National Laboratories/California). The Livermore site's sanitary sewer discharges are sampled continuously, daily, weekly, and monthly to satisfy various permit compliance requirements.

LLNL achieved greater than 99% compliance with LWRP permit limits covering discharges into the sanitary sewer during 1997. However, five notices of violation (NOVs) were written for violations that occurred. It should be emphasized that LLNL's sewer diversion system is designed to prevent large releases, not to preclude NOVs resulting from small releases to the sewer. One was for silver and pH exceedances, a second for a mercury exceedance, a third for a pH exceedance, a fourth for two lead exceedances, and a fifth for four different pH exceedances. Thirteen inadvertent discharges were detected by the continuous monitoring system in 1997, all involving either a metal, acid, or base, and more than half of these instances warranted sewage diversion. During 1997, no sewer releases exceeded discharge limits for radioactive materials.

Water Monitoring

Surface water sampling and analysis are a large part of the LLNL surveillance and compliance monitoring effort for the Livermore site, Site 300, and their surrounding regions. The waters monitored include storm water runoff; rainfall; reservoirs and ponds, the Livermore site's swimming pool and Drainage Retention Basin; tap water; treated ground water discharges; and wastewater discharges from cooling towers at Site 300. Depending on location, the samples may be analyzed for gross alpha and gross beta radiation, radionuclides such as tritium and uranium, and nonradioactive pollutants, including solvents, metals, explosives, pesticides, and a wide range of organic compounds; monitored properties include total suspended and total dissolved solids, conductivity, and pH. In addition, fish bioassays are performed annually.

Ground water in the Livermore Valley and the Altamont Hills is monitored to assess the progress of remediation efforts in areas of known contamination, to test that LLNL operations do not significantly impact local water sources, and to comply with numerous federal, state, and local permits. Ground water samples are routinely measured for tritium, uranium, and other radioisotopes; gross radioactivity; toxic metals; a wide range of organic chemicals; and other general contaminant indicators. Special consideration is given to monitoring those dissolved elements and organic compounds that are known to be toxic in trace amounts.

Expressed as a percentage of the regulatory maximum contaminant level (MCL) for tritium in drinking water, the 1997 maximum tritium activities measured in Livermore site and Livermore Valley surface and drinking water were at a level of 2%; the highest tritium activity measured in rainfall was 9%; and the maximum tritium activity in storm water runoff was 3%, save for one exceptional sample where the result was 49% of the MCL. Maximum gross alpha and gross beta activities in storm water were 28% and 33%, respectively, of the MCLs for these radiations. Fish toxicity tests conducted in 1997 indicated that LLNL storm water runoff has no adverse impact on off-site biota; the 96-hour survival rate for fish in undiluted storm water collected at the Livermore site perimeter was 100%.

The impact of Livermore site and Site 300 operations on off-site ground waters is minimal. At the Livermore site, no monitored radioactive or inorganic nonradioactive constituent in any off-site well was found to exceed primary drinking water MCLs. In on-site wells instances of chromium and nitrates above the primary MCL were found, but have not migrated off site. At Site 300, tritiated water and depleted uranium have been released to ground water from landfills and firing tables, but the boundaries of the slowly-moving ground water plumes lie entirely within site boundaries. The shallow ground water beneath Site 300 contains volatile organic compounds (VOCs), tritium, nitrates, Freon, and depleted uranium, but presents no current health risks, because this contaminated water is not used as a potable domestic, livestock, or industrial water supply. Except for VOCs being remediated under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) at both sites, there is little or no evidence of adverse impacts on ground waters beyond the sites. In particular, the VOC plumes that were advancing to the west and southwest of the Livermore site are being pulled back to the site and treated.

Soil and Sediment Monitoring

Soil and sediment sample analyses for the Livermore site in 1997 indicated that the impact of Laboratory operations on these media were insignificant and unchanged from previous years. The highest measured level of plutonium (isotopes 239 and 240) represented 2.2% of the EPA preliminary remediation goal for commercial or industrial sites; this occurred at the Livermore Water Reclamation Plant (LWRP). Most constituents of concern were measured at background or trace concentrations, or were below the limit of detection. At Site 300, the concentrations of radionuclides and beryllium in soil samples were representative of background or naturally occurring levels, as in previous years, with the exception of two sampling locations. Elevated concentrations of uranium-238 found at locations 812N and 851N in 1997 were attributed to contamination by debris from firing table experiments.

As noted below in the section on “Safety Evaluation and Health Assessment,” the federal Agency for Toxic Substances and Disease Registry (ATSDR), working with the California Department of Health Services (DHS), conducted site team meetings in 1997 on the issue of plutonium in Big Trees Park, Livermore. While stating that levels of plutonium were not a health concern, it was concluded that questions of how the plutonium got into the park and the extent of the contamination warranted further investigation. A plan to do further soil sampling is currently being devised.

Vegetation and Foodstuff Monitoring

Area vegetation and foodstuff are monitored for their tritium content. Tritium concentrations in samples taken near the Livermore site were found to be higher than those in samples taken from more distant locations, consistent with the trend of data over the last 16 years. The tritium concentrations in vegetation in 1997 were quite low and not significantly different than those reported the previous year. Potential ingestion doses estimated from the measured concentrations are well below levels of concern, even when organically bound tritium is taken into account. In 1997, as in the past, tritium concentrations in Livermore Valley wines were slightly above those for wines tested from Europe and other locations in California; but the tritium levels are quite low. Mean levels for the 1997 sampling year, using data from all areas, were not significantly different from those reported for the past several sampling years. Even the highest detected value, 8.0 becquerels per liter (215 picocuries per liter), represents only 1.1% of the amount of tritium California allows in drinking water (no health standards exist for radionuclides in wine).

Radiological Dose Assessment

Radiological dose-assessment modeling, using EPA-mandated computer models, actual LLNL meteorology, population distributions appropriate to the two sites, and 1997 radionuclide inventory and monitoring data, was conducted this past year for all facilities and all potential emission points at the Livermore site and Site 300.

The public doses we report result from air releases of radionuclides during routine operations and (when applicable) from accidents. The principal exposure pathways are taken into account: internal exposures from inhalation of air and ingestion of foodstuff and drinking water, and external exposures from contaminated ground and immersion in contaminated air. Releases of radioactivity from LLNL via the water pathway do not directly contribute to the public dose, since they are not consumed by any individual.

The calculated total potential dose for the sitewide maximally exposed individual (SW-MEI), i.e., a hypothetical member of the public having the greatest possible exposure from Livermore site operations in 1997, was 0.97 microsievert (0.097 millirem), nearly the same as last year’s value. Eighty percent of this amount was attributed to the Tritium facility, resulting mainly from decontamination and decommissioning activities. Trends in this SW-MEI dose for the Livermore site over the last six years show levels in the range 1.0 to 0.4 microsievert/y (0.1 to 0.04 millirem/y), down from 2.40 microsievert/y (0.24 millirem/y) in 1990. These are small radiation quantities, exhibiting large percentage, but small absolute value, fluctuations from one year to the next.

The calculated total potential dose to a hypothetical public individual having the greatest possible exposure at Site 300 during 1997 was 0.20 microsievert (0.020 millirem), which is the lowest level since these estimates of public dose from Site 300 operations were first made eight years ago. Explosive tests at the Building 801 firing table accounted for about 55% of this potential dose, while resuspension of depleted uranium in soils at the site (deposited by explosives experiments in previous years) accounted for 45%. This total dose is about 61% of the previous year’s value, reflecting decreased activity at the firing tables in 1997. Trends in annual dose levels from Site 300 operations show that year-to-year fluctuations by about a factor of two are typical.

In determining the total dose to the public from LLNL activities, unplanned or accidental releases must be included in the assessment, as well as releases from routine operations. There was one unplanned release of radioactivity from the Livermore site in 1997. A small quantity of curium-244 escaped from Building 513 during a waste shredding operation. Analyses based on monitoring data gathered during and subsequent to the primary release event concluded that the SW-MEI dose from this accidental release was 0.0021 microsievert (0.00021 millirem). LLNL received a Preliminary Notice of Violation from DOE Headquarters for this accident and submitted an action plan designed to prevent any similar reoccurrence.

The most significant radiological effluent for the Livermore site continues to be tritium, the radioactive isotope of hydrogen. For Site 300, depleted uranium (containing isotopes with atomic weights 238, 235, and 234 in the weight percentages 99.8, 0.2, and 0.0005, respectively) is the dominant contributor to off-site dose.

Radiological doses to the maximally exposed public individuals from Livermore site and Site 300 emissions amounted to about 0.97% and 0.20%, respectively, of the EPA National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulatory standard. These doses are a small fraction (about 1/3000) of the doses received by these populations from natural background radiation. Thus, the potential radiological doses from LLNL operations in 1997 were well within regulatory limits and were very small compared to doses from natural background radiation sources.

Environmental Compliance and Program Activities

LLNL works to ensure that its operations comply with all environmental laws and federal, state, and local regulatory guidelines. Many activities related to water, air, waste, waste reduction, community “right to know,” and other environmental issues were addressed in 1997.

Safety Evaluation and Public Health Assessment

LLNL’s system of safety management was intensively evaluated by DOE’s Office of Oversight in 1997. A 25-person evaluation team spent six weeks in this review that examined DOE/OAK and the University of California, as well. Livermore site facilities reviewed included the Plutonium Facility, Hazardous Waste Management Facility, and the National Ignition Facility, and topical areas such as radiation protection and chemical and high-explosive safety were considered. Conclusions of the evaluation were generally positive; some areas needing improvement were identified and are being acted upon.

The federal Agency for Toxic Substances and Disease Registry (ATSDR) conducted site team meetings in 1997 and contracted with the California Department of Health Services to draft two health consultations related to Livermore site operations. The first concerned levels of plutonium in Big Trees Park, Livermore (mentioned earlier in this summary in the Soil and Sediment Monitoring section); the second assessed potential impacts of Livermore site operations on the municipal water supply. LLNL is working with ATSDR to resolve comments on the health consultations and identify and execute appropriate follow-up activities.

Ground Water Remediation

Both the Livermore site and Site 300 are Superfund sites undergoing remedial activities under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). LLNL's primary treatment technology to remediate contaminated ground water is pump-and-treat technology. In 1997, seven treatment facilities at the Livermore site processed over 870 million liters of ground water, removing nearly 110 kilograms of volatile organic compounds (VOCs) plus smaller quantities of dissolved fuel hydrocarbons (FHCs). These efforts at control and remediation have stopped the off-site westward migration of VOC plumes from the Livermore site and have reduced plume size. In 1997, LLNL increased its use of portable treatment units; these provide a relatively inexpensive alternative to the fixed treatment units that have been used since 1989. Significant progress also occurred at Site 300, where more than 6 kilograms of VOCs were removed from soil and ground water in four treatment areas. Since initiating cleanup, the concentrations of Trichloroethene in the Central General Services Area of Site 300, for example, have been reduced from 9400 parts per billion (ppb) in 1993 to 380 ppb in 1997.

Waste Minimization and Pollution Prevention

A hierarchical approach to waste reduction, consisting of source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal, has been adopted by LLNL, in accordance with EPA guidelines and DOE policy, and applied to all types of waste.

LLNL now employs a weighted ranking system to prioritize and evaluate its waste streams. Cost, type of waste, and operational aspects are emphasized, rather than simply considering total waste volume. The 20 waste stream components having highest priority under this system contrast sharply with the corresponding set under a waste volume ranking; transuranic and transuranic-mixed and low-level wastes now rank as highest priority for LLNL, even though their quantities are rather low.

The trend in routine waste generation at LLNL over the past eight years shows dramatic reductions in all four categories: radioactive, mixed, hazardous, and sanitary. Comparing 1997 to 1990 levels, these categories have undergone reductions of 85%, 90%, 87%, and 28%, respectively. The total waste diverted from landfills in 1997 was more than 40,000 tons, almost 10 times the total for two years earlier and twice the previous year's amount; beneficial reuse of soil on site was responsible for most of this increase. LLNL's recycling percentage for nonhazardous waste was 92% in 1997, far in excess of the DOE-stated goal of achieving 33% by the end of 1999. In fiscal year 1997, the Laboratory received a National DOE P2 (pollution prevention) award for its achievements in solid waste recycling of construction and demolition debris.

The Laboratory continued to search for and capitalize on opportunities to eliminate, reduce, recover, or recycle potential pollutants to all media, including air, water, soil, sediments, and biota. As one example, replacement and recycling of ozone-depleting Freon 113 (used in parts cleaning operations and as a coolant or refrigerant) is a high priority; by the end of 1997, Freon 113 had been replaced in all but one parts-cleaning operation.

Chemical inventories at LLNL are tracked through the use of bar codes, hand-held bar code laser scanners, and customized software in a computerized chemical inventory system called ChemTrack. The 1997 inventory featured 175,000 chemical containers ranging from 210-liter drums to gram-quantity vials. ChemTrack minimizes the purchase of new chemicals, thereby reducing procurement costs and the generation of hazardous waste, and enhances LLNL's ability to provide federally required toxic release information.

Air, Wastewater, and Water Compliance

LLNL continued to perform all activities necessary to comply with clean air and clean water requirements. In 1997, the Bay Area Air Quality Management District (BAAQMD) issued or renewed 140 permits to operate for the Livermore site. The San Joaquin Valley Unified Air Pollution Control District issued or renewed 43 permits for Site 300 operations. LLNL has permits for underground and aboveground storage tanks and for discharge of treated ground water, industrial and sanitary sewage, and storm water. Site 300 has additional permits for inactive landfills, cooling tower discharges, operation of the sewer lagoon, septic tanks, and leach fields. The Laboratory complies with all requirements for self-monitoring and inspections associated with these permits.

Environmental Occurrences

Notification of environmental occurrences at the Laboratory is required under a number of environmental laws, regulations, and DOE orders. LLNL responded to 12 incidents that required federal and/or state agency notification during 1997. None of these caused adverse impact to human health or the environment.

Endangered Species and Paleontological Resources

Two of the three known natural populations in the world of the large-flowered fiddleneck (*Amsinckia grandiflora*), a federally listed endangered plant species, occur at Site 300, which has been designated a critical habitat for the plant. In 1997, the number of fiddleneck plants in two native populations at the site drastically declined, likely because of heavy rain runoff and increased exotic grass cover. The experimental population of this plant was not diminished. Two additional sensitive plant species were identified at Site 300 in 1997: the big tarplant (*Blepharazonia plumosa*) and the diamond-petaled poppy (*Eschscholzia rhombipetala*). Regarding animals, biological assessment surveys on the Livermore site and Site 300 were performed for special status species at 83 project construction areas in 1997. Two new populations of the federally threatened red-legged frog (*Rana aurora draytonii*) were found across Site 300 in wetlands and seasonal pools and identified in the Arroyo Los Positas on the Livermore site. White-tailed kites (*Elanus lecurus*), state-protected raptors, successfully nested at the Livermore site and fledged young.

During soil excavation for the National Ignition Facility at the Livermore site, bones from a 14,000-year-old mammoth were found at a depth of about 30 ft and greater. These will be cataloged into the University of California Berkeley Museum of Paleontology collection.

Conclusion

The current techniques used at LLNL for environmental monitoring are very sensitive, allowing detection at extremely low levels of constituents. The combination of surveillance and effluent monitoring, source characterization, and computer modeling show that radiological doses to the public caused by LLNL operations are less than 1.0% of regulatory standards and are about 3000 times smaller than the doses received from background radiation. The analytical results and evaluations generally show continuing low contaminant levels, reflecting both decreased operations and the responsiveness of the Laboratory in controlling pollutants.

In 1997, significant achievements were made in environmental compliance activities related to water, air, waste, and waste reduction. Ground water remediation activities have stopped the westward migration of plumes at the Livermore site; waste minimization efforts have significantly reduced the amount of waste generated in LLNL operations; recycling efforts have diminished the quantity of waste sent to landfills; and efforts at waste reduction and pollution prevention have capitalized on a variety of opportunities to reduce or eliminate, recover, or recycle potential pollutants.

In summary, the results of the 1997 environmental programs demonstrate that LLNL is committed to protecting the environment and ensuring that its operations are conducted in accordance with applicable federal, state, and local laws and regulations. The environmental impacts of LLNL operations are minimal and pose no threat to the public or the environment.

1

Site Overview

Introduction

Meteorology and geography can play primary roles in how the environment is affected by human actions. Dispersal of particles in air, for example, is influenced by the wind and rain, which in turn are influenced by geographical characteristics. Similarly, the movement of ground water is constrained by the particular geology of a site. Thus, knowledge of wind, rainfall, geology, and geographical characteristics are used to model the effects that operations at Lawrence Livermore National Laboratory might have on the surrounding environment. Some history and a description of these characteristics help us understand the importance of the Laboratory's meteorological and geographic setting.

Operations

The mission of LLNL is to serve as a national resource in science and engineering, with a special responsibility for nuclear weapons. Laboratory activities focus on global security, energy, global ecology, biomedicine, economic competitiveness, and science and mathematics education. The Laboratory's mission is dynamic and has broadened over the years to meet new national needs.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, and medical departments—necessary to support its operations and about 8500 personnel.

Location

LLNL consists of two sites—the main laboratory site located in Livermore, California (Livermore site) in Alameda County, and the Experimental Test Site (Site 300) located near Tracy, California, in San Joaquin and Alameda Counties (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

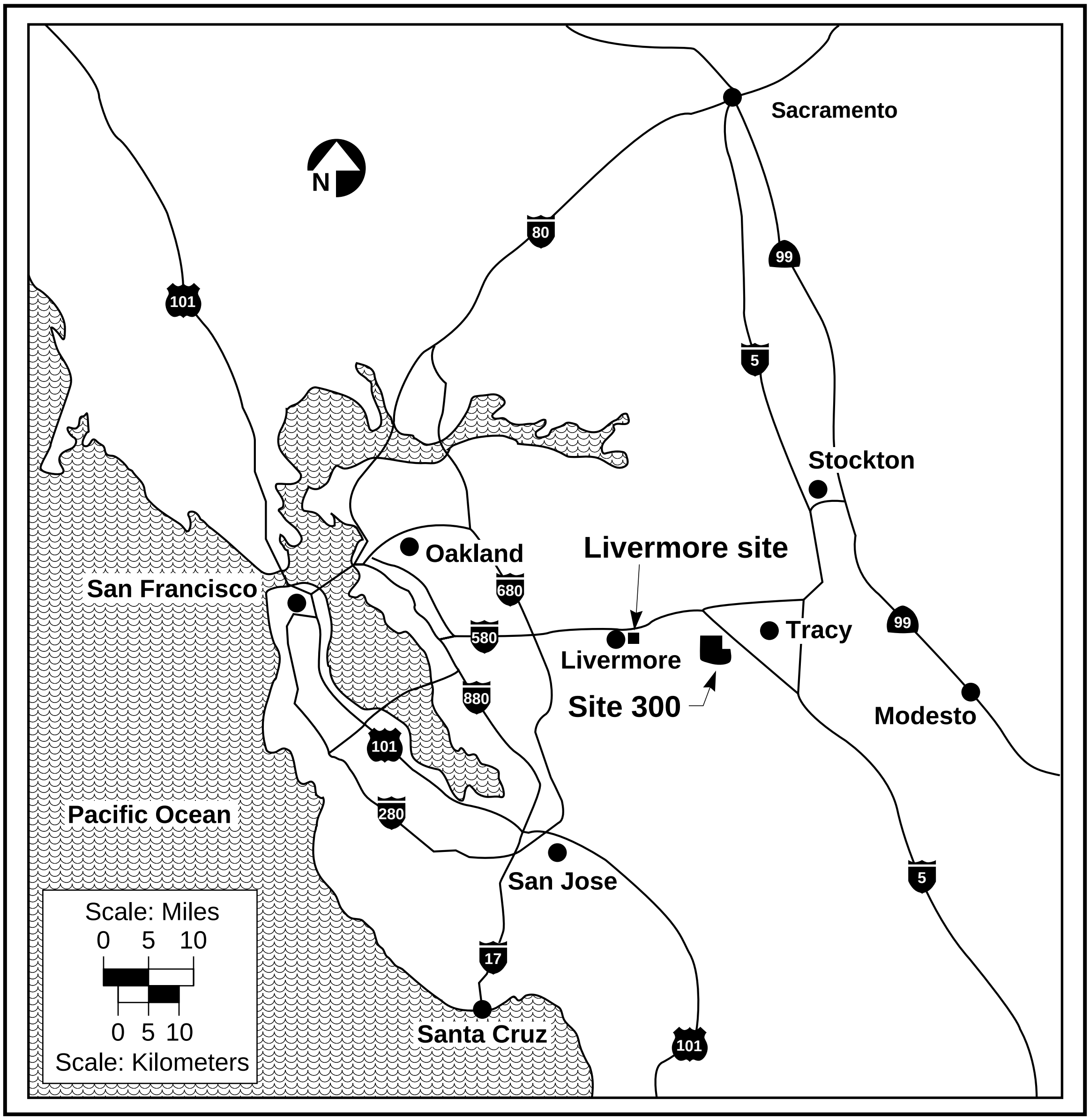

Figure 1-1. Locations of LLNL Livermore site and Site 300.

LLNL was founded at the Livermore site in 1952 at a former U.S. Navy training base. At that time the location was relatively isolated, being approximately 1.6 km from the Livermore city limits. Over time, Livermore evolved from a small town of fewer than 7000 people when the Laboratory began to its present population of about 68,000. The economy, which had been primarily agricultural, diversified to include light industry and business parks. Within the last few years, low-density, single-family residential developments have begun to fill the formerly vacant fields. Livermore residences are now near LLNL’s western boundary.

LLNL's Livermore site occupies an area of 3.28 km^2, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories (SNL)/California, operated by Lockheed-Martin under DOE contract. SNL/California engages in research and development associated with nuclear weapons systems engineering, as well as related national security tasks. Although their primary missions are similar, LLNL and SNL/California are separate entities, each with its own management and each reporting to a different DOE operations office.

To the south of LLNL, there are also some low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards. A business park lies to the southwest. Farther south, property is primarily open space and ranchettes, with some agricultural use. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills that define the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare parcel of open space to the northeast has been rezoned to allow development of light industry.

Site 300, LLNL's Experimental Test Facility, is located 20 km east of the Livermore site in San Joaquin County in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 km^2. It is in close proximity to two other testing sites: PRIMEX/Physics International operates a testing site that is adjacent and to the east of Site 300, and SRI International operates another site, located approximately 1 km south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills to the northwest. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 46,000), located 10 km to the northeast.

Meteorology

Meteorological data (including wind speed, wind direction, rainfall, relative humidity, solar radiation, and air temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. A detailed review of the climatology for LLNL can be found in Gouveia and Chapman (1989). The mean annual temperature for 1997 was 15°C. Temperatures range from –5°C during some predawn winter mornings to 40°C during some summer afternoons.

Both rainfall and wind exhibit strong seasonal patterns. Annual wind data for the Livermore site are given in **Figure 1-2** and **Table 1-1**. These data show that greater than 50% of the wind comes from the south-southwest to westerly direction.

These wind patterns tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. The wind blows from the northeast primarily during the winter storm season. Most precipitation occurs between October and April, with very little rainfall during the warmer months. The highest and lowest annual rainfalls on record are 812 and 122 mm. The average annual rainfall is 368 mm. In 1997, the Livermore site received 249 mm of rain.

The meteorological conditions at Site 300, while generally similar to the Livermore site, are modified by higher elevation and more pronounced relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-3** and **Table 1-2**. The data show that these winds are more consistently from the west-southwest and reach greater speeds than at the Livermore site. The increased wind speed and elevation of much of the site result in afternoon temperatures that are typically lower than those for the Livermore site. Rainfall for 1997 was 193 mm at Site 300.

Geology

Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley, the most prominent valley in the Diablo Range, is an east-west trending structural and topographic trough that is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays, at an average thickness of about 100 m. The valley is approximately 25-km long and averages 11 km in width. The valley floor is at its highest elevation of 220 m above sea level along the eastern margin and gradually dips to 92 m at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow intermittently. Major arroyos are depicted in Chapter 7 (**Figure 7-1**).

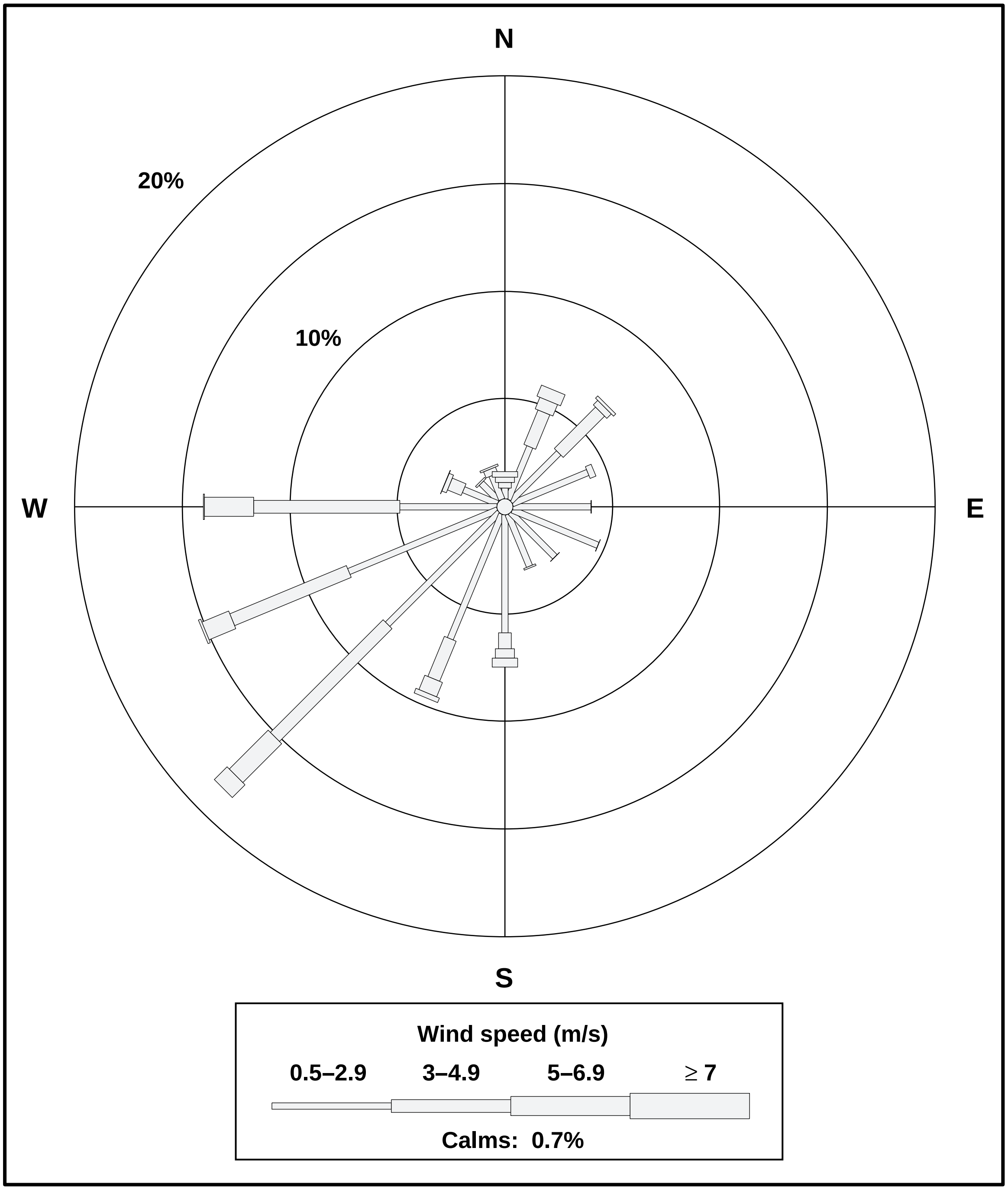

Figure 1-2. Wind rose showing the frequency of occurrence for wind speed and direction at the Livermore site, 1997.

Table 1-1. Wind rose data for LLNL's Livermore site at the 10-m level for 1997. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding.

	Wind speed range (m/s)					
Direction	**0.0–0.4**	**0.5–2.9**	**3.0–4.9**	**5.0–6.9**	**≥7.0**	**Total**
NNE	0.05	2.65	1.73	0.58	0.55	5.6
NE	0.05	3.17	2.72	0.29	0.15	6.4
ENE	0.05	3.80	0.29	0.00	0.00	4.1
E	0.05	3.63	0.02	0.00	0.00	3.7
ESE	0.05	4.31	0.00	0.00	0.00	4.4
SE	0.05	2.92	0.00	0.00	0.00	3.0
SSE	0.05	2.62	0.08	0.00	0.00	2.7
S	0.05	5.49	0.74	0.44	0.41	7.1
SSW	0.05	6.27	2.02	0.72	0.23	9.3
SW	0.05	7.35	7.41	2.56	0.84	18.2
WSW	0.05	7.49	5.87	1.35	0.11	14.9
W	0.05	4.52	6.80	2.29	0.05	13.7
WNW	0.05	1.71	0.69	0.22	0.00	2.7
NW	0.05	1.18	0.09	0.00	0.00	1.3
NNW	0.05	1.20	0.31	0.09	0.00	1.7
N	0.05	0.50	0.26	0.25	0.26	1.3
Total	**0.7**	**58.8**	**29.1**	**8.8**	**2.6**	**100**

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation ranges from approximately 538 m above sea level at the northwestern corner of the site to approximately 150 m in the southeast portion.

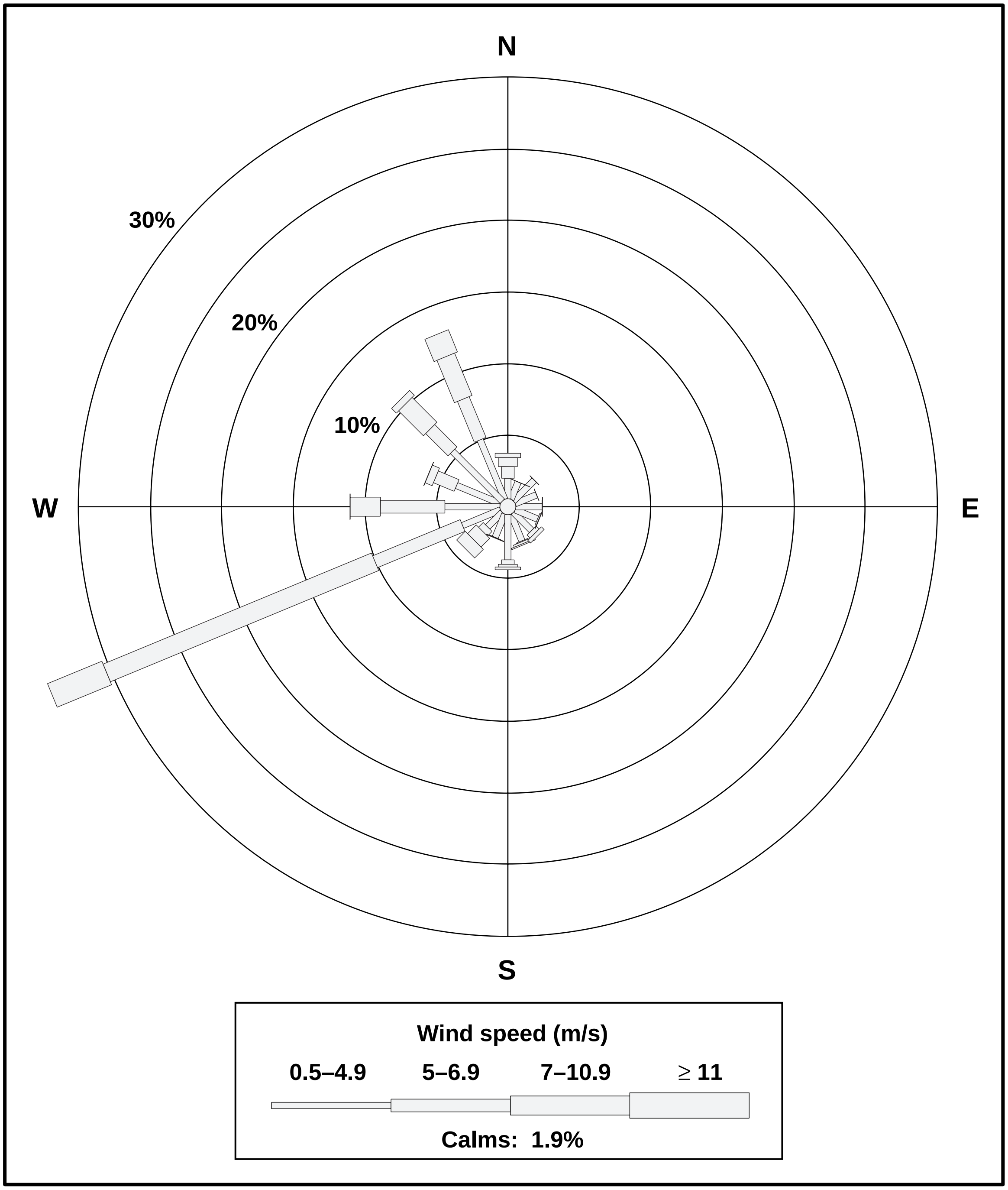

Figure 1-3. Wind rose showing the frequency of occurrence for wind speed and direction at Site 300, 1997.

Table 1-2. Wind rose data for LLNL's Site 300 at the 10-m level for 1997. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding.

	Wind speed range (m/s)					
Direction	**0.0–0.4**	**0.5–4.9**	**5.0–6.9**	**7.0–10.9**	**≥11.0**	**Total**
NNE	0.12	1.31	0.00	0.00	0.00	1.4
NE	0.12	2.06	0.00	0.00	0.00	2.2
ENE	0.12	1.61	0.00	0.00	0.00	1.7
E	0.12	1.83	0.02	0.02	0.00	2.0
ESE	0.12	1.69	0.09	0.02	0.00	1.9
SE	0.12	1.79	0.30	0.27	0.00	2.5
SSE	0.12	2.02	0.06	0.15	0.09	2.4
S	0.12	3.16	0.31	0.19	0.18	4.0
SSW	0.12	1.76	0.02	0.03	0.00	1.9
SW	0.12	1.44	0.47	0.85	0.86	3.7
WSW	0.12	2.87	6.62	20.29	4.11	34.0
W	0.12	3.84	4.51	2.11	0.02	10.6
WNW	0.12	3.32	1.57	0.54	0.00	5.6
NW	0.12	4.91	2.21	2.45	0.47	10.2
NNW	0.12	4.50	3.09	3.19	1.68	12.6
N	0.12	1.43	0.82	0.63	0.30	3.3
Total	**1.9**	**39.5**	**20.1**	**30.7**	**7.7**	**100**

Hydrogeology

Livermore Site

The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; and Thorpe et al. 1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for ground water management in the Livermore Valley basin (San Francisco Bay RWQCB 1982a and b).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley ground water basin, an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain ground water levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the water table varies in depth from about 10 to 40 m. **Figure 1-4** shows a contour map of water table elevations (meters above mean sea level) for the Livermore site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-4** are generally maintained. At the eastern edge of the Livermore site, ground water gradients (change in vertical elevation per unit of horizontal distance) are relatively steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Ground water flow under most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of ground water recovery and remediation in the southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 m/day (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an average ground water velocity estimate of 20 m/y (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most ground water occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable layers;

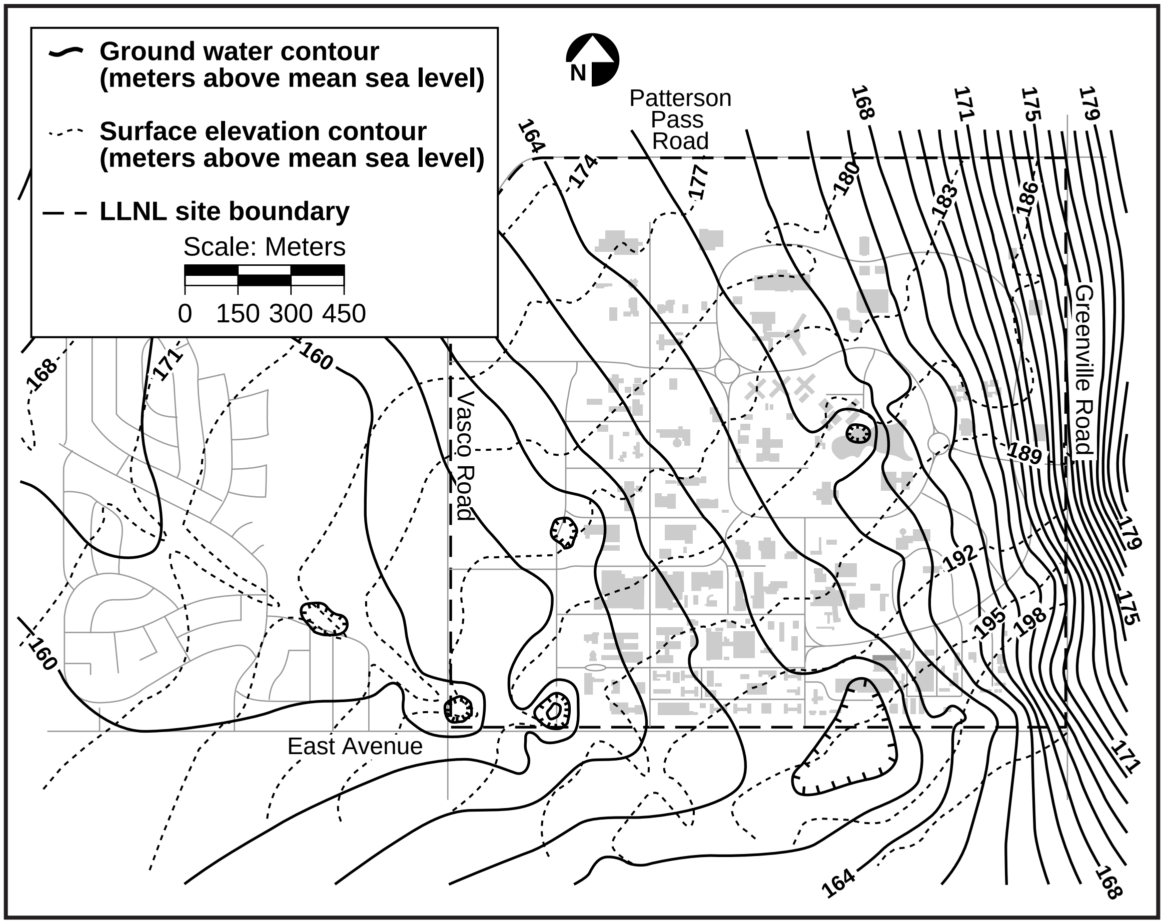

Figure 1-4. Approximate ground water and surface elevation contours, Livermore site and vicinity.

normally they are discontinuous and highly localized. Because water quality generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

Fine-grained siltstone and claystone interbeds may confine the ground water and act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers, but is generally unconfined elsewhere.

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, ground water in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, ground water in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly lower blue sandstone, stratigraphically near the base of the formation, generally contains confined water. Wells located in the western part of the General Services Area are completed in this aquifer and are used to supply drinking and process water.

Figure 1-5 shows the elevation contours for water in the regional aquifer at Site 300. This map of the piezometric surface (the elevation to which water rises in a well that penetrates a confined or unconfined aquifer) is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock, or where permeable bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Further information on the hydrology of both the Livermore site and Site 300 can be found in the ground water protection information in Chapters 8 and 9.

Summary

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationships with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year additional information is gained to allow us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, soil, water, vegetation, and foodstuff—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each medium used to monitor the environment.

Authors Acknowledgment

We acknowledge the work of Frank Gouveia, Michael Taffet, Richard Blake, Kris Surano, and Janice Butler in preparing this chapter.

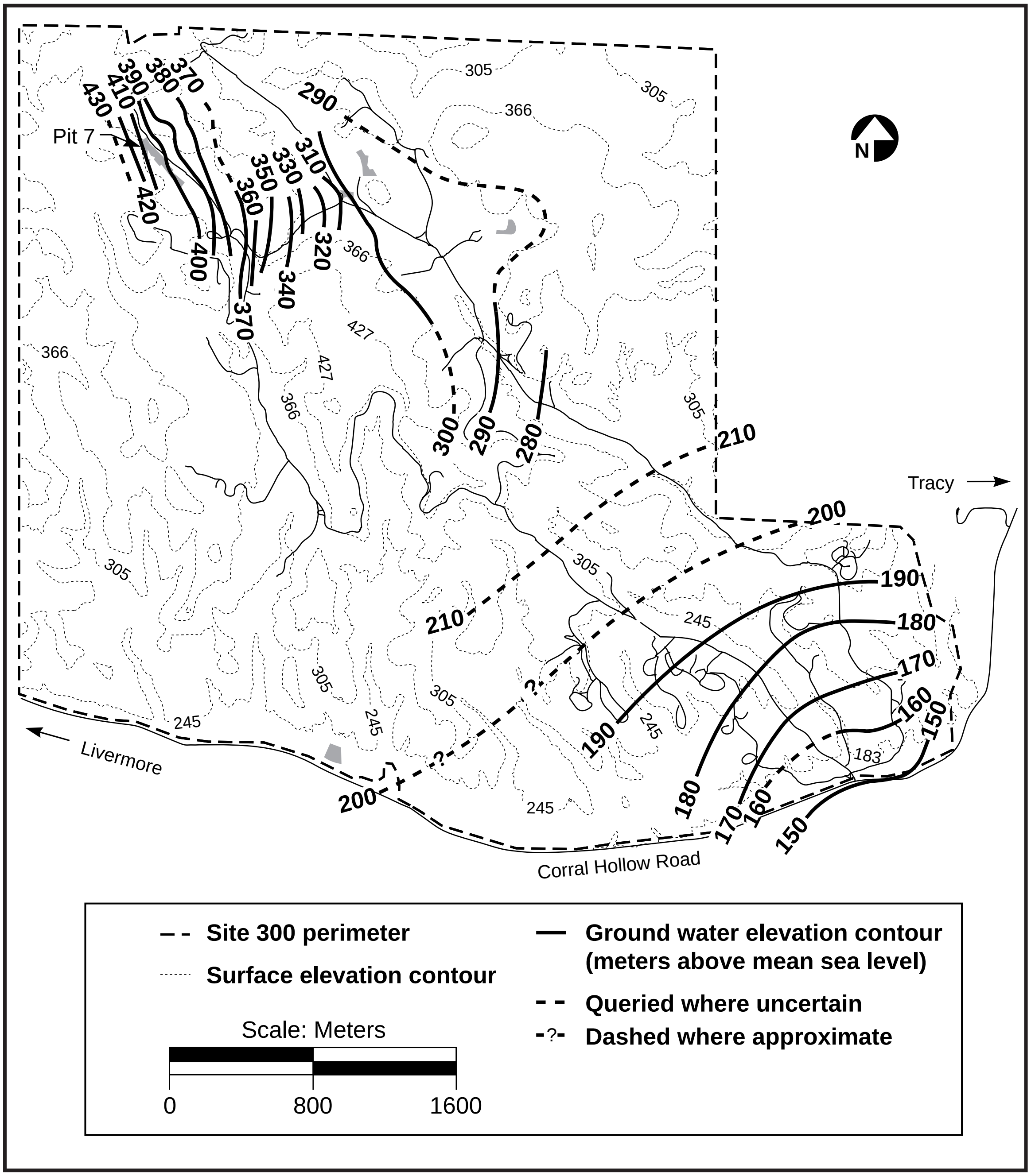

Figure 1-5. Approximate ground water elevations in principal continuous water-bearing zones at Site 300.

2 Compliance Summary

Introduction

During 1997, Lawrence Livermore National Laboratory participated in numerous activities to comply with federal, state, and local environmental regulations as well as internal requirements and Department of Energy (DOE) orders. Activities related to air, water, waste, waste reduction, community "right to know," protection of sensitive resources, and other environmental issues were carried out at the Livermore site and Site 300. Many documents concerned with these activities and other environmental issues are available for public viewing at the LLNL Visitors Center and the Livermore and Tracy public libraries. A wide range of compliance activities are summarized in the following sections.

CERCLA/SARA, Title I

LLNL has two projects that are under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)/Superfund Amendment and Reauthorization Act (SARA), Title 1. These are the Livermore Site Ground Water Project and the Site 300 Ground Water Project.

Livermore Site Ground Water Project

The Ground Water Project (GWP) complies with provisions specified in a federal facility agreement (FFA) entered into by the U.S. Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (RWQCB). As required by the agreement, the project addresses compliance issues through investigations of potential contamination source areas (such as suspected old release sites, solvent handling areas, and leaking underground tank systems), continued monitoring of ground water, and remediation. The ground water constituents of concern are volatile organic compounds (VOCs), primarily trichloroethene (TCE) and tetrachloroethene (PCE). These contaminants are present primarily within the site boundary but to some extent at the site boundary and beyond, mainly to the west and south of the site. Locations of ground water and vapor treatment facilities are shown in **Figure 2-1**. On-site treatment facilities

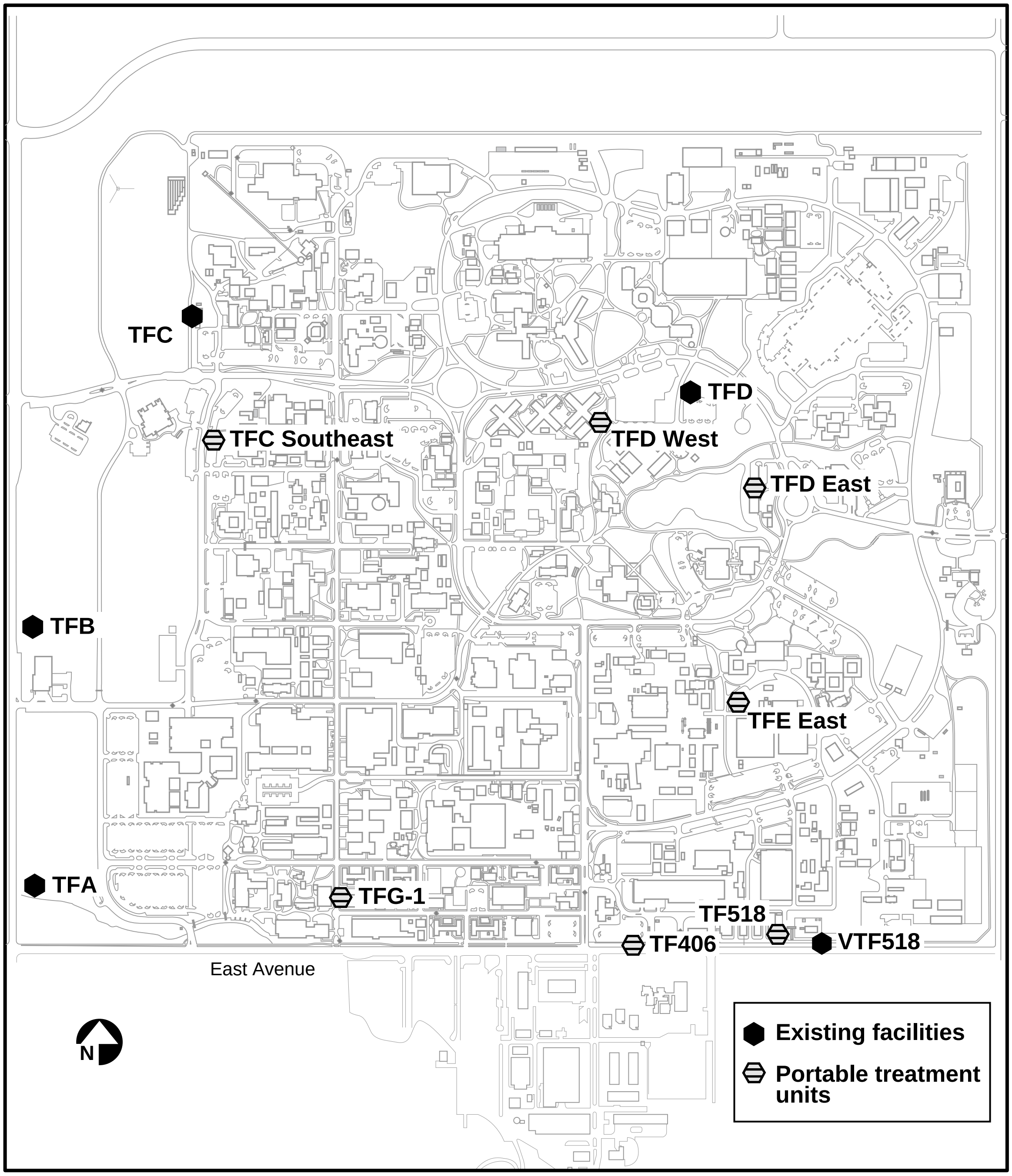

Figure 2-1. Location of existing ground water and vapor (V) treatment facilities.

are generally situated in areas of high concentrations of VOCs. (See **Figure 8-4** in Chapter 8 for an isoconcentration contour map of VOCs at the Livermore site and environs.) However, Treatment Facilities A, B, and C (TFA, TFB, and TFC) are located at areas of lower contaminant concentrations downgradient from high concentration “hot spots” to aid in remediation of contaminated ground water at and beyond the site boundary.

Pump-and-treat, the primary treatment technology employed at the Livermore site to remediate contaminated ground water, employs a dense network of ground water extraction wells, monitoring wells, pipelines, and surface treatment facilities.

In 1997, LLNL increased its use of portable treatment units (PTUs). These relatively inexpensive units provide an alternative to the fixed treatment units that have been used since 1989.

Documentation

Documentation required by the regulatory agencies in 1997 was submitted and is summarized in Appendix C. The first Five-Year Review for the Livermore site (Berg et al. 1997a) was approved by the U.S. Environmental Protection Agency (EPA) in December 1997. The review concluded that Livermore site remedial actions continue to meet the objectives of the 1992 Record of Decision. Two Explanations of Significant Differences (ESDs) were also prepared and approved by the regulatory agencies. The first ESD described a change in remediation treatment from ultraviolet light/hydrogen peroxide (UV/H_2O_2) and air stripping to air stripping only at TFA and TFB (Berg et al. 1997b). The second ESD concerned a change in metals discharge requirements based on wet and dry season beneficial use (Berg et al. 1997c). Both ESDs were issued in April 1997. A Draft Action Memorandum (Bainer and Berg 1997) for an emergency removal action was prepared in response to the discovery of undocumented buried capacitors and drums during excavation for the National Ignition Facility (NIF). Appropriate public notification and information activities were conducted in support of this removal action. The Draft Action Memorandum was submitted on October 31, 1997, for a 30-day community review and comment period. A Closeout Report for the emergency removal action was submitted in December 1997 (Bainer and Littlejohn 1997). After responding to community comments, DOE/LLNL issued the final Action Memorandum in February 1998.

Milestones and Activities

The six 1997 Remedial Action Implementation Plan milestones (Dresen et al. 1993) for the Livermore site were reached ahead of schedule. Greater quantities of VOCs were removed from ground water in 1997 by using more wells and more PTUs. Remediation activities at the Livermore site are summarized in **Table 2-1** and discussed in greater

Table 2-1. Volatile organic compounds (VOCs) removed from ground water and soil at the Livermore site.

Treatment facility[a]	Startup date	1997		Cumulative totals	
		Water treated (ML)[b]	VOCs removed (kg)	Water treated (ML)[b]	VOCs removed (kg)
TFA	9/89	483	18.4	1475	93.4
TFB	10/90	64	6.8	246	26.8
TFC	10/93	87	9.4	136	15.4
TFD	9/94	181	55.0	230	73
TFE	11/96	36	15.9	38	16.7
TFG1	4/96	12	0.6	15	1.2
TF406	8/96	8.7	0.9	10	1.1
		Soil vapor treated (m^3)	VOCs removed (kg)	Soil vapor treated (m^3)	VOCs removed (kg)
VTF518[b]	9/95	123,000	40.6	175,000	106.6

a Includes fixed and portable units.

b ML = 1 million liters.

detail in Chapters 7 and 8. In short summary, Livermore site environmental restoration activities in 1997 included the following:

- A high-efficiency air stripper began operation at TFA in June 1997. The air stripper, which is more cost effective and operates at a higher capacity, replaces the UV / H_2O_2 system that had been in use since 1989.
- In situ pilot testing of catalytic reductive dehalogenation at Trailer 5475 began on August 8, 1997. This technology is based on the reaction of dissolved hydrogen with VOCs on a palladium-alumina catalyst to form ethane and chloride. Tests showed that the efficiency of VOC removal was greater than 95% and that mass removal rates were high.
- Buried drums and capacitors discovered during excavation for the NIF were removed (Bainer and Berg 1997) and transported to licensed disposal facilities in Utah.

- Alameda County Flood Control and Conservation District, Zone 7 (Zone 7) joined with LLNL to discuss a cooperative effort to model the water needs for the Livermore Valley's increasing population and agricultural needs. As part of a preliminary investigation, LLNL employed the two-dimensional CFEST flow model (Tompson et al. 1995) to estimate ground water flow in the basin and test the influence of different rates of extraction and reinjection within the basin.
- Construction of ground water Treatment Facility 518 (TF518) began in 1997, and PTU518 started operating in January 1998.

Community Relations

In August 1997, DOE / LLNL celebrated five years of successful environmental restoration at the Livermore site. The celebration was attended by elected officials, DOE, regulatory agencies, LLNL, and community representatives.

The Community Work Group (CWG) met twice in 1997 to discuss the DOE budget, progress of Livermore site cleanup, the procedural changes outlined in the two ESDs, the Priority List / Consensus Statement (Lamarre and Littlejohn 1997), the Five-Year Review, and the Draft Remedial Design Report No. 4 (Berg et al. 1997a). Correspondence and communication with CWG members continued throughout the year.

Other Livermore site community relations activities in 1997 included communicating and meeting with local, regional, and national interest groups; public presentations including those to local realtors, national and northern California peace leaders, and international student and business groups; producing and distributing the *Environmental Community Letter*; maintaining the Information Repositories and the Administrative Record; conducting tours of site environmental activities; and responding to public and news media inquiries. DOE / LLNL met three times with members of Tri-Valley Citizens Against a Radioactive Environment (CAREs) and their technical advisor as part of the activities funded by an EPA technical assistance grant.

Site 300 Ground Water Project

At Site 300, remedial investigations, feasibility studies, engineering evaluation and cost analyses, remedial designs, and remedial actions are ongoing. Environmental investigations and cleanup activities began in 1981. Site 300 became a CERCLA / Superfund site in 1991, when it was placed on the National Priorities List (NPL).

2 Compliance Summary

Site 300 investigations and remedial actions are conducted under the joint oversight of the EPA, the Central Valley RWQCB, and the DTSC and the authority of a federal facility agreement (FFA) for the site. (There are separate FFAs for Site 300 and the Livermore site.) During November 1996, an addendum containing updated scope and milestone due dates was added to the FFA after approval by the regulatory agencies (U.S. Department of Energy 1996a). During 1997, LLNL submitted all required regulatory documents (see Appendix C) and performed all actions stipulated in the FFA on or ahead of schedule. The study areas are shown in **Figure 2-2**. The major constituents of concern are listed in **Table 2-2**.

Four treatment facilities that remove and treat VOCs, primarily TCE, are currently in operation at Site 300. **Table 2-3** summarizes 1997 and cumulative totals of volumes and masses of contaminants removed from ground water and soil vapor.

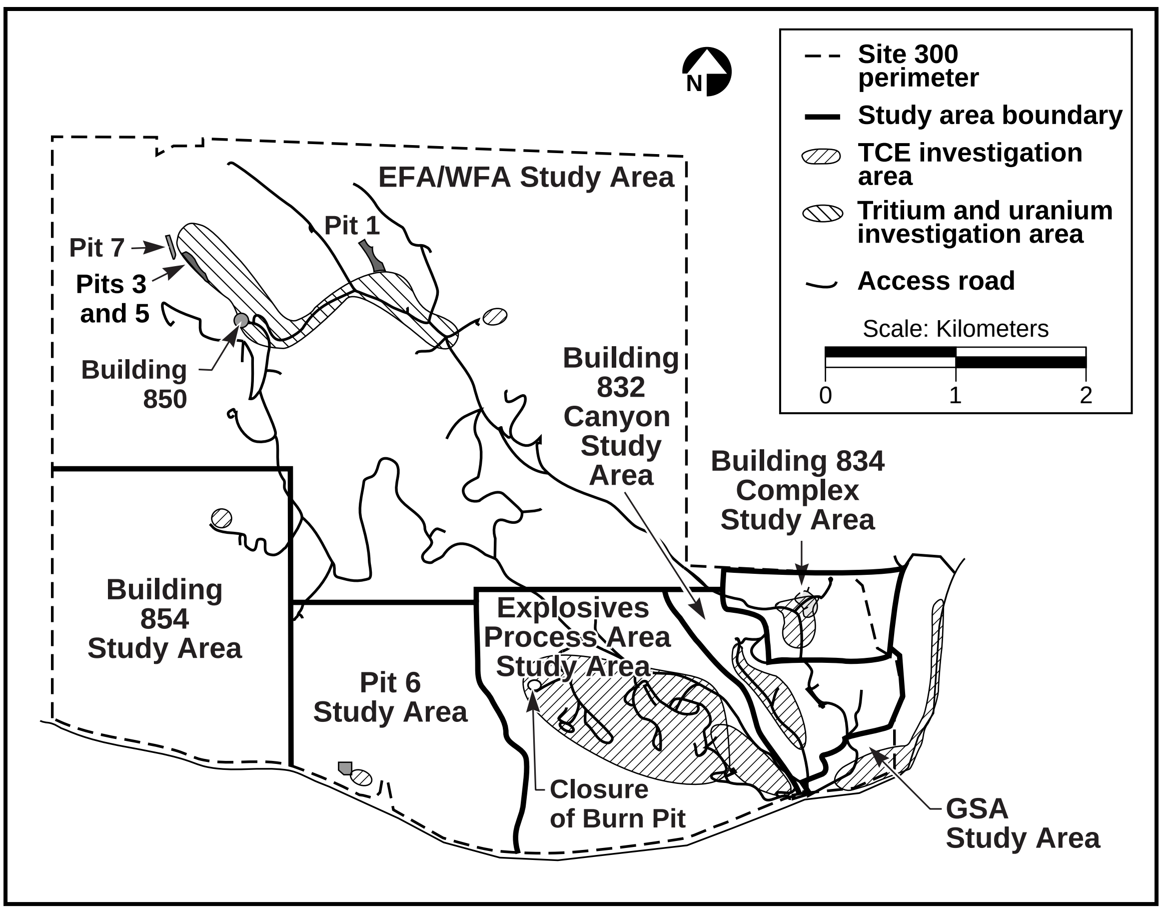

Figure 2-2. Environmental restoration study areas and activities at Site 300.

Table 2-2. Major constituents of concern found in soil, rock, and ground water at Site 300.

Study area	Constituent of concern
General Services Area (GSA)	VOCs (primarily TCE)
Building 834 Complex	VOCs (primarily TCE), organosilicate oil
High Explosives Process Area	VOCs (primarily TCE) HE[a] (primarily HMX[b])
East and West Firing Areas (EFA/WFA)	Tritium Depleted uranium VOCs (primarily TCE)
Building 854	VOCs (primarily TCE)
Pit 6	VOCs (primarily TCE)
Building 832 Canyon	TCE

a HE = high explosives.

b HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

Table 2-3. Volatile organic compounds (VOCs) removed from ground water and soil at Site 300.

Treatment area	Startup date	1997		Cumulative totals	
		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
General Services Area					
Eastern GWTF[b]	6/91	80.8	0.35	409	5.0
Central GWTF	4/93	0.7	0.73	3.2	5.6
Building 834	10/95	90.8	5.2	91.0	16.7
		Soil vapor treated (m^3)	**VOCs removed (kg)**	**Soil vapor treated (m^3)**	**VOCs removed (kg)**
General Services Area					
Central	1994	47,438	0.72	446,135	30.3

a ML = million liters.

b GWTF = ground water treatment facility.

Study Area Highlights and Activities

Background information for LLNL activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994) and in previous Environmental Reports (Harrach et al. 1996 and 1997). Remediation activities are summarized in **Table 2-3**. See Chapters 7 and 8 for a more complete discussion of 1997 monitoring activities and results for Site 300 environmental restoration study areas.

General Services Area (GSA). Details of 1997 activities are contained in the following reports: *The Final Record of Decision for the GSA Operable Unit* (U.S. Department of Energy 1997), which was signed on February 7, 1997, and the *Draft Remedial Design* document (Rueth et al. 1997), submitted to the regulatory agencies in August 1997. The remedial design document includes the Contingency Plan and Compliance Monitoring Plan for the GSA operable unit (OU). There are two ground water TCE plumes and two corresponding treatment facilities in each of the Eastern and Central GSAs.

In the Eastern GSA, the air-sparging ground water treatment system (GWTS) and tank in the Eastern GSA were replaced by several aqueous-phase granulated activated carbon (GAC) adsorption units, which are effective in removing VOCs from ground water, less complex in both design and operation than air-sparging technology, and less expensive than the sparging tanks. The units also eliminated the need for the air permit previously required by the San Joaquin Valley Unified Air Pollution Control District for treatment of the contaminated vapor stream; this will reduce regulatory compliance monitoring and reporting requirements.

LLNL estimates that eight more years of ground water extraction and treatment will be required to achieve and maintain ground water VOC concentrations below maximum contamination levels (MCLs) at the Eastern GSA.

In the Central GSA, air-sparging treatment tanks have been replaced with air-strippers in a portable treatment unit (PTU), which is more cost effective and easier to deploy to another Site 300 operating unit. Trichloroethene (TCE) concentrations in Central GSA GWTS influent have been reduced from 9400 ppb in April 1993 to 380 ppb in October 1997.

Building 834 Complex. The Building 834 GWTS was operated continuously from October 1996 through May 1997, when the system was shut down to prepare for a small-scale test to assess the potential of enhancing TCE recovery through the use of a surfactant. The Building 834 GWTS is expected to resume operation in 1998.

Explosives Process Area. Continued assessment of chemical data indicate that although natural attenuation is reducing the extent and maximum concentration of VOCs at the Building 815 operable unit, contaminants continue to migrate toward the southern Site 300 boundary. Consequently, a Building 815 OU engineering evaluation / cost analysis report was submitted to regulatory agencies who accepted the report in December.

East and West Firing Area. This year, an assessment of annual tritium inventories in ground water from 1985 to 1997 was completed. The analysis, which included the inventories of tritium in the vadose zone available for leaching to ground water indicated that the two tritium plumes emanating from the landfill are stable with regard to measured tritium concentrations and area impacted, while the Building 850 plume is decreasing at the radioactive decay rate. Although tritium continues to leach into ground water from landfilled materials from past operations, the long term trend in total ground water tritium activity is one of decreasing activity at approximately the radioactive decay rate of tritium.

Total uranium activities in excess of the California MCL continued to be measured in ground water samples from several monitoring wells at the Pits 3 and 5 areas; several of these wells also yielded water samples bearing isotopic ratios indicative of depleted uranium. Conversely, samples of ground water from several wells in the area contain uranium activities that exceed the state MCL, but bear natural-uranium isotopic signatures. Analyses of ground water samples from several wells adjacent to Building 850 also indicate depleted-uranium signatures; these samples do not exceed the California MCL for uranium. Three small plumes of uranium in ground water emanate from each of Pits 5 and 7 and the Building 850 firing table. Conservative ground water fate and transport modeling indicates that total uranium activity will be at background levels by the time any depleted-uranium-bearing ground water reaches the Site 300 boundary.

In 1997, LLNL submitted to the regulatory agencies the *Draft Engineering Evaluation/Cost Analysis Report for the Building 850/Pits 3 and 5 Operable Unit* (Taffet, et al. 1997). The document contains an analysis of a number of removal action elements for the operable unit.

Trichloroethene occurs in a small ground water plume monitored by two wells at the Building 801 firing table. Since monitoring began in 1987, concentrations have dropped from a maximum of 6 µg / L, to less than 2 µg / L. Freon 113 at ground water concentrations significantly below the California MCL of 1.2 ppm is present near Pit 1 and is the result of spills at Building 865 Advanced Testing Accelerator. Remedial investigations for these areas are planned for the future.

Building 854 Study Area. During 1997, LLNL determined the extent of TCE in soil, soil vapor, and ground water. Trichloroethene in the ground water was found to arise principally from leaks in the former overhead TCE brine system at Buildings 854E and 854F. During 1997, LLNL began preparation of the *Characterization Summary Report for the Building 854 OU*; this document will be submitted to the regulatory agencies in 1998.

Pit 6 Area. The Title II design package for the capping of Pit 6 was submitted to the regulatory agencies on December 18, 1996. A public meeting was held on January 15, 1997. During 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA non-time-critical removal action. The objectives of the capping are to: (1) isolate the buried waste from infiltrating rain water; (2) divert surface water from the landfill; (3) eliminate safety hazards from subsidence into voids in the buried waste; (4) mitigate risk from potential inhalation of vapors from the subsurface; and (5) reduce ground water recharge near the contaminant plumes. The total cost of constructing the landfill cap was about $1,500,000. Selectively substituting geosynthetic for natural materials (clay) saved more than $500,000, while maintaining the same high performance standards for impermeability and durability.

Building 832 Canyon Study Area. Ground water samples collected from wells in the Building 832 Canyon area contain TCE and nitrates at concentrations in excess of MCLs. The maximum concentration of TCE reported in ground water was 7 ppm. Samples of surface water and water from shallow wells indicate that a plume of TCE in ground water has reached the southern Site 300 boundary.

In 1997, the *Characterization Summary for the LLNL Site 300 Building 832 Canyon Operable Unit* (Ziagos and Ko 1997) was submitted to regulatory agencies. This report contains the results of the last several years of intensive drilling, sampling, and data analysis in the operable unit. Ongoing analysis of the nature and extent of subsurface contamination has indicated that the dominant chemical of concern is TCE, which has been found at a maximum concentration of 30 ppb in shallow alluvial ground water. The TCE plume in the Building 832 Canyon appears to have its origin in releases at deactivated test cells at Buildings 832 and 830. Trichloroethene from these source areas has migrated into the Building 832 Canyon and forms a plume of relatively continuously diminishing TCE that extends 900 m (3000 ft) to the Site 300 boundary, where it is at concentrations of about 1 ppb. As the TCE moves into and down the canyon, it occurs in several deeper hydrogeologic units.

The first step toward TCE mass removal in the operable unit was completed with the submittal and acceptance of the “Building 832 Canyon Operable Unit Treatability Study Workplan” in November 1997. This workplan sets forth plans for ground water and soil vapor TCE extraction and treatment in 1998 and beyond, using portable treatment units, solar-powered water activated-carbon treatment units, and soil vapor extraction systems. Also under consideration is the use of a subsurface iron filings permeable reactive treatment wall in the lower canyon area to intercept the TCE-laden ground water, destroy the TCE and degradation products, and help control the migration of the TCE plume off site.

Community Relations

LLNL Site 300 community relations activities in 1997 included communications and meetings with local, regional, and national interest groups; other community organizations; public presentations, including those to local realtors; maintaining the Information Repositories and the Administrative Record; conducting tours of site environmental restoration activities; and responding to public and news media inquiries. DOE/LLNL met three times with members of Tri-Valley Citizens Against a Radioactive Environment (CAREs) and their technical advisor as part of the activities funded by an EPA Technical Assistance Grant. A public workshop for the Pit 6 Removal Action capping was held on January 15, 1997.

SARA, Title III

Title III of the Superfund Amendment and Reauthorization Act (SARA) of 1986 is known as the Emergency Planning and Community Right-to-Know Act (EPCRA). It requires owners or operators of facilities that handle certain hazardous chemicals on site to provide information on the release, storage, and use of those chemicals to organizations responsible for emergency response planning. Executive Order 12856, signed by President Clinton in August 1993, directs all federal agencies to comply with the requirements of EPCRA, including the SARA 313 Toxic Release Inventory Program.

EPCRA requirements and LLNL compliance are summarized in **Table 2-4**. **Tables 2-5** and **2-6** identify those chemicals reported by LLNL for the Livermore site and Site 300, respectively under Title III Section 311 during 1997.

Activities Requiring Permits

Permits are required for a number of LLNL environmental activities related to air, water, hazardous waste, sewerable waste, storage tanks, and medical waste. **Table 2-7** summarizes these permits. Inspections and tours by the permitting agencies in 1997 are summarized in **Table 2-8**.

Table 2-4. Summary of LLNL compliance with EPCRA in 1997.

EPCRA requirement	Brief description	Compliance
302 Planning notification	Operator must notify SERC[(a)] of presence of extremely hazardous substance.	In California, operator must notify CEPRC[(b)] of presence of extremely hazardous substances above threshold planning quantities. Originally submitted May 1987.
303 Planning notification	Operator must designate a facility representative to serve as emergency response coordinator.	Update submitted March 28, 1997.
304 Release notification	Releases of certain hazardous substances must be reported to SERC and LEPC[(c)].	No EPCRA-listed extremely hazardous substances were released above reportable quantities.
311 MSDS/Chem inventory	Operator must submit MSDSs or chemical list to SERC, LEPC, and fire department.	**Tables 2-5** and **2-6**.
312 MSDS/Chem inventory	Operator must submit hazardous chemical inventory to appropriate county.	Business Plans and chemical inventory submitted to San Joaquin County (January 14, 1997) and Alameda County (January 15, 1997).
313 Toxic Release Inventory	Operator must submit Form R to USEPA[(d)] and California EPA for toxic chemicals released.	Form R for Freon 113 submitted June 27, 1997 to DOE; DOE forwarded to USEPA and California EPA on July 30, 1997.

[a] State Emergency Response Commission.

[b] Chemical Emergency Planning and Response Commission.

[c] Local Emergency Planning Committee.

[d] U.S. Environmental Protection Agency.

Table 2-5. Livermore site, SARA, Title III, Section 311, Chemical List.[a]

Livermore site chemicals	Physical hazards			Health hazards	
	Fire	Pressure	Reactivity	Acute	Chronic
Ammonium hydroxide				X	
Argon		X		X	
Brayco 889, coolant	X				
Carbon, activated	X				
Chlorine		X	X	X	
Diesel fuel	X				
Ethyl alcohol	X			X	X
Freon 113				X	
Gasoline	X			X	X
Helium		X		X	
Hydrochloric acid				X	X
Hydrofluoric acid		Some containers	X	X	X
Hydrogen	X	X		X	
Hydrogen peroxide (<52%)			X		
Insulating oil, inhibiting	X				
Lead (bricks and ingots)				X	X
Methane	X	X		X	
Nitric acid	X		X	X	X
Nitric oxide		X	X	X	
Nitrous oxide		X		X	
Nitrogen		X		X	
Oxygen		X	X		
Paint	X				
Sulfuric acid			X	X	X

[a] Physical and health hazard information obtained primarily from Material Safety Data Sheets (MSDS).

Table 2-6. Site 300, SARA, Title III, Section 311, Chemical List.[a]

Site 300 chemicals	Physical hazards			Health hazards	
	Fire	Pressure	Reactivity	Acute	Chronic
Chlorine		X		X	
Bis(2,2-dinitro-2-fluoroethyl) formal in methylene chloride	—[b]		—[b]	X	X
Diesel fuel	X				
Gasoline	X			X	X
High explosives			X		
Lead (bricks)				X	X
Nitrogen		X			
Oil, hydraulic	X				
Oil, inhibited insulating	X				
Oil, transformer	X				

[a] Physical and health hazard information obtained primarily from Material Safety Data Sheets (MSDS).

[b] Dangerous fire or explosion risk in neat form (solvent evaporates).

Clean Air Act—Air Quality Management Activities

Air permits are obtained from the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and from the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) for Site 300. In 1997, BAAQMD issued or renewed air permits for 140 air emission sources for the Livermore site. For 1997, SJVUAPCD issued or renewed air permits for 43 air emission sources for Site 300 (see **Table 2-7**). During 1997, air district inspectors found no deficiencies at the Livermore site. At Site 300, the only issue raised was related to the joint Air Resources Board (ARB) / SJVUAPCD review of long-standing policies regarding waste explosives burning, as discussed in the Hazardous Waste Permitting section, later in this chapter.

Table 2-7. Summary of permits active in 1997.

Type of permit	Livermore site	Site 300
Air	140 permits from BAAQMD. Various equipment, including boilers, emergency generators, cold cleaners, ultrasonic cleaners, degreasers, printing press operations, manual wipe cleaning operations, metal machining and finishing operations, silk screening operations, silk screen washers, paint spray booths, adhesives operations, diamond turning machine cleaning operation, image tube fabrication, optic coating operations, gravity retort, storage tanks containing volatile organic compounds (VOCs) in excess of 10%, planetary mixers, plating tanks, drum crusher, semiconductor operations, diesel air compressor engines, ground water air strippers/ dryers, ovens, material handling equipment, sewer diversion system, wave soldering machine, oil and water separator, fire test cells, oil shale hopper and preheater, oil shale combuster, gasoline dispensing operation, resin mixing operation, paper pulverizer system, and firing tank.	43 permits from SJVUAPCD. Various equipment, including boilers, emergency generators, paint spray booth, ground water air strippers, soil vapor extraction units, woodworking cyclone, gasoline dispensing operation, and drying ovens.
Water	WDR Order No. 88-075 for discharges of treated ground water from TFA to percolation pits and recharge basin. WDR Order No. 95-174, NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat non-storm water discharges to surface waters. WDR Order No. 92-08-DWQ, NPDES General Permit No. CAS000002, Bldg. 132, Site ID No. 201S300881, DWTF Site ID No. 201S305140, Soil Reuse Project ID No. 2015305529 and National Ignition Facility, Site ID No. 201S306762, and for discharges of storm water associated with construction activities impacting two hectares or more. One project completed under Army Corps of Engineers Nationwide Permit and 401 Waiver of Water Quality Certification, three streambed alteration agreements. FFA, ground water investigation/remediation.	WDR Order No. 92-08-DWQ, NPDES General Permit No. CAS000002, Contained Firing Facility Chemistry Magazine Loop, Site ID No. 5B39S307131. WDR Order No. 93-100 for post-closure for discharges of storm water associated with construction activities impacting two hectares or more monitoring requirements for two Class I landfills. WDR Order No. 94-131, NPDES Permit No. CA0081396 for discharges of storm water associated with industrial activities and from cooling towers. WDR Order No. 96-248 for operation of two Class II surface impoundments, a domestic sewage lagoon, and percolation pits. WDR Order No. 97-242, NPDES Permit No. CA0082651 for discharges of treated ground water from the eastern General Services Area treatment unit. One streambed alteration agreement. FFA ground water investigation/remediation. Fifty-two registered, Class V injection wells.

Table 2-7. Summary of permits active in 1997 (continued).

Type of permit	Livermore site	Site 300
Waste	EPD ID No. CA2890012584. Authorization to perform waste resin mixing in Unit CE231-1 and Unit CE443-1 under Conditional Exemption tiered permitting. Authorization to construct and operate Building 612 Size Reduction Unit, Area 514-1 Container Storage/Treatment Unit Group and Area 514 Quadruple Tank Unit under interim status modification. Closure under interim status of the Area 514 Storage Tank 514-R501 Unit (25,000-gallon Storage Tank). Continued authorization to operate 19 waste storage units and 13 waste treatment units under interim status.	EPA ID No. CA2890090002. Part B Permit—Site 300 and Container Storage Area (B-883) Explosives Waste Storage Facility (issued May 23, 1996). Part B Permit—Explosives Waste Treatment Facility—Site 300 (issued October 9, 1997). Docket HWCA 92/93-031.
Sewer	Discharge Permit Nos. 1250 (97/98), for discharges of wastewater to the sanitary sewer. 1510G (97) for discharges of sewerable ground water from sitewide ground water restoration activity.	
Tanks	Thirteen underground petroleum and hazardous waste storage tank permits.	One permit covering five underground petroleum product tanks.
Other	ACEHS medical waste permit for treatment and storage.	SJCPHS medical waste limited quantity hauling exemption

[a] Permit numbers are based on actual permitted units maintained and renewed by LLNL during 1997.

National Emission Standards for Hazardous Air Pollutants

Demonstration of compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radionuclide emissions to air (Radionuclide NESHAPs, 40 CFR 61, Subpart H) requires that all potential sources be evaluated and the potential radiological dose to the sitewide maximally exposed public individual (SW-MEI) be determined.

Compliance with two dose limits must be evaluated. First, the integrated dose to the SW-MEI from all sources of radionuclide emissions to air at a site must not exceed 100 microsieverts per year (µSv/y) (10 millirem per year [mrem/y]). Second, each source (stack) with the potential for unmitigated emissions resulting in any dose greater than 1 µSv/y (0.1 mrem/y) must be continuously monitored using systems that meet requirements stated in the regulations.

Table 2-8. Inspections and tours of LLNL facilities by external agencies in 1997.

Medium	Description	Agency	Date	Finding
Livermore site				
Air	Emission sources	BAAQMD	1/22 2/5 2/18 3/12 3/19	No violations
Water/natural and cultural resources	Streambed alteration	CDFG	6/30 9/15	No violations
	Sediment sampling	DTSC	7/29	No violations
	Arroyo Maintenance Project	USFWS	9/9	No violations
	Visit archeological site	ACOE	9/15	No violations
	Mammoth bones/NIF excavation	DOI	12/21	No violations
Waste	Hazardous-waste management facilities and waste accumulation areas	DTSC	3/17–3/21	3 violations[a]
	Storage and treatment facilities	DTSC	10/28	No violations
	Vehicles used for transporting hazardous materials	CHP	12/9–12/10	7 minor violations
Sewer	Building 321, Building 341 abrasive machining operations, Building 432, general inspection	LWRP	2/4	No violations
	Compliance sampling	LWRP	10/1–10/2 10/16	No violations
	Categorical sampling	LWRP	11/25	No violations
Tanks	Installation and closure of USTs	ACEHS	1/16 11/18	No violations
Other	Medical waste	ACEHS	9/10	No violations
Site 300				
Air	Emission sources	SJVUAPCD	8/19	No violations
	Radionuclide NESHAPs site inspection	EPA	9/3	No violations
Waste	Hazardous-waste storage and treatment facilities, waste accumulation areas, and satellite accumulation areas	DTSC	1/29	No violations[a]
Wastewater	Permitted operations	CVRWQCB	4/16 9/16	No violations

[a] During these inspections there were also issues raised relative to low-level radioactive waste containing California-only hazardous constituents. These issues are being resolved in a Memorandum of Understanding between DOE and DTSC.

The *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998) reported to DOE and EPA the total calculated SW-MEI radiological doses for the Livermore site and Site 300 to be 0.97 µSv / y (0.097 mrem / y) and 0.20 µSv / y (0.020 mrem / y), respectively. The reported doses include contributions from both point sources and diffuse sources. Modeling was based on a combination of effluent monitoring data and radionuclide inventory data. The totals are well below the 100 µSv / y (10 mrem / y) dose limits defined by the NESHAPs regulations. The details of these data are included in this report (see Chapter 12, Radiological Dose Assessment). These 1997 dose values are comparable to those reported for 1996, which were 0.93 µSv / y (0.093 mrem / y) and 0.33 µSv / y (0.033 mrem / y) for the Livermore site and Site 300, respectively.

There was one unplanned atmospheric radionuclide release from the Livermore site in 1997, which released curium-244 from Building 513 during waste shredding activities. Several types of data were recorded during and subsequent to the initial release event, including routine surveillance air monitoring data recorded outside the building at several field locations, and respirator data, continuous air monitoring data, and high-volume air sampler data recorded inside the building. Based on these data, several different analytical approaches were used to quantify the amount of curium-244 released into the atmosphere by this incident and to evaluate the maximum potential dose to the public. The "best estimates" were that several hundred nanocuries were released, producing a dose to the SW-MEI of 2.1×10^{-3} µSv (2.1×10^{-4} mrem). This incident and its analyses are described in greater detail in a letter from LLNL to EPA Region IX (Fisher 1998), and in this report's Chapter 12: Radiological Dose Assessment, and in the *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998a). There were no unplanned atmospheric releases at Site 300 in 1997.

In 1997, LLNL maintained continuous radionuclide emissions monitoring of Building 331 (the Tritium Facility), Building 332 (the Plutonium Building), the seismically strengthened portion of Building 251, and three other buildings (see Chapter 12).

On September 3, 1997, the U.S. EPA Region IX made a radionuclide-NESHAPs inspection of Site 300, with DOE in attendance. LLNL personnel summarized operations at Site 300 and construction of the Contained Firing Facility (CFF), reviewed the modeling protocol for Site 300 explosives experiments, reviewed diffuse source calculations, and gave a NESHAPs compliance overview. A facilities tour included the CFF construction site and ambient air monitoring stations. EPA and DOE personnel were briefed on the unplanned release from Building 513 mentioned earlier and detailed written information required by EPA was provided. This incident and its analyses are described in the NESHAPs Annual Report and in a detailed letter from LLNL to EPA Region IX, as noted above. LLNL's Site 300 activities were found to be in compliance with 40 CFR 61 Subpart H, and no additional compliance activities were required.

Clean Water Act and Related State Programs

Preserving clean water is one objective of local, state, and federal regulations. The National Pollutant Discharge Elimination System (NPDES) under the Federal Clean Water Act establishes permit requirements for discharges into navigable waterways. In addition, the State of California requires permits, known as Waste Discharge Requirements (WDRs), for any discharges of wastes affecting the beneficial uses of waters of the state. The regional water quality control boards (RWQCBs) are responsible for issuing and enforcing both permits. The Livermore Water Reclamation Plant (LWRP) requires permits for discharges of sewerable water to the city sanitary sewer system. The Army Corps of Engineers (ACOE) issues permits for work in navigable waterways below the ordinary high water mark and for controlling dredge and fill operations in waters of the United States. The State Water Resources Control Board (SWRCB) issues water quality certifications for this work if the regional water quality control boards do not waive the requirement for the water quality certification. The California Department of Fish and Game (CDFG) under the Fish and Game Code Section 1601 et seq. requires streambed alteration agreements for any work that may disturb or impact rivers, streams, or lakes. Finally, the Safe Drinking Water Act (SWDA) requires registration and management of injection wells to protect underground sources of drinking water. Water permits are summarized in **Table 2-7** and discussed in detail in Chapters 6, 7, and 8.

Ground Water and Surface Water

Discharges of treated ground water to surface water drainage courses and percolation ponds at LLNL are governed by NPDES permits, WDRs, and CERCLA Records of Decision (see **Table 2-7**). Details of surface water discharges are found in Chapter 7 of this report. Details of ground water monitoring are found in Chapter 8 of this report, the *LLNL Ground Water Project 1996 Annual Report* (Hoffman et al. 1997), and the LLNL Remedial Program Manager's quarterly reports (McConachie and Brown 1996; Ko et al. 1996; Littlejohn and Lamarre 1996 and 1997). LLNL discharges storm water associated with industrial activities, low-threat nonstorm water, and various process waters to surface waters, percolation pits, surface impoundments and a sewage lagoon under four NPDES permits and three WDRs (see Chapters 7 and 8). LLNL received no Notices of Violation (NOVs) in 1997 from the regional water quality control boards that issued the NPDES and WDR permits. However, LLNL identified nonconformance with one of the four permits. NPDES nonconformances are summarized below in **Table 2-9**.

Table 2-9. Summary of compliance with NPDES permits.

Permit No.	Outfall	Nonconformance	Date(s) of nonconformance	Description–solution
CAS000002	Arroyo Las Positas (Livermore site)	Building 132: Required inspections not performed	3/97	Revise LLNL construction program
		Building 132: Improper storage of materials, spill	4/97	Cleaned up contaminated material
		Building 132: Work commenced prior to SWPPP[a] submittal	5/97	Require SWPPP prior to issuing Notice to Proceed
CA0030023	Arroyo Las Positas and Arroyo Seco (Livermore site)	None	None	None
CA0081396	Corral Hollow Creek (Site 300)	None	None	None
CA0082651	Corral Hollow Creek (Site 300)	None	None	None

a SWPPP = Storm Water Pollution Prevention Plan.

In addition, LLNL was unable to comply with prohibitions in WDR No. 96-248 on March 27 and on July 16. On March 27, the retention tank pump for B823 at Site 300 failed, resulting in a release of between 1.5 to 2 gallons of wastewater to ground. On July 16, two more spills occurred at Site 300. One spill resulted from an algae plug in the wastewater line at B817 and resulted in a release of 5 gallons of untreated wastewater. The other also released 5 gallons of wastewater when a pump at B823 overheated and shut down. Wastewater overflowed the retention tank and secondary containment with a small volume being discharged to the ground. These discharges were reported orally and in writing to the Central Valley RWQCB. Finally, on April 16 the TCE concentration (5.5 µg/L) in discharges from TFA exceeded the discharge limit in WDR 88-075 for total volatile organic compounds (5.0 µg/L). Details can be found in Chapter 8, Ground Water Remediation.

LLNL continued construction operations for three projects and started operations for two other projects. These activities are covered by the California General Construction Activity permit (see **Table 2-7**). Continuing operations included construction of Building 132, the nonhazardous waste portions of the Decontamination and Waste Treatment Facility (DWTF), and the Soil Reuse Project (previously referred to as the North Buffer Zone Regrading). In 1997, LLNL submitted two Notices of Intent (NOIs) for the construction of the National Ignition Facility at the Livermore site and the Contained Firing Facility and Chemistry Magazine Loop project at Site 300.

In December 1997, the Central Valley RWQCB issued WDR Order No. 97-242 (NPDES Permit No. CA0082651) for the continued discharge of treated ground water from the Eastern General Services Area at Site 300 to Corral Hollow Creek. This order replaced WDR Order No. 92-052.

At the request of the San Francisco Bay RWQCB, LLNL submitted a Report of Waste Discharge (ROWD) for the Soil Reuse Project in April. This project beneficially reuses excess soil generated from on-site construction projects in various regrading and landscaping projects throughout the Livermore site. The San Francisco Bay RWQCB has not acted on the ROWD formally; however, they provided verbal approval to proceed with certain portions of the project.

The Central Valley RWQCB inspected the Site 300 permitted facilities in April 1997 with the result of no violations. An additional visit to Site 300 in September was made by the Central Valley RWQCB to see a tear in the liner of the lower surface impoundment in the Explosives Process Area. The San Francisco Bay RWQCB did not inspect any Livermore site facilities in 1997.

Sewerable Water

The Livermore site's sanitary sewer discharges are sampled continuously, daily, weekly, and monthly to satisfy various permit compliance requirements. The monitoring results for the LLNL effluent are reported monthly to the LWRP. In 1997, LLNL achieved greater than 99% compliance with LWRP Permit 1250 covering wastewater discharges to the sanitary sewer. However, five Notices of Violation (NOVs) were written for permit violations that occurred in 1997. (The LWRP issued three of the NOVs in 1997 and two in 1998.) The first NOV, issued in March 1997, was for silver and pH exceedances on February 5 and 12, respectively. The NOV specifically targeted these two discharges, but treated the pH exceedance as a continuation of the low pH exceedances of 1996. In September 1997, the LWRP issued the second NOV for a July 4 mercury exceedance. The third NOV (and final NOV for 1997) was issued in October 1997 for a pH exceedance on August 21, 1997. The NOV specifically targeted the August 21 discharge, but considered the exceedance as part of a pattern of pH exceedances that began in January 1996. The fourth and fifth NOVs were issued in January 1998 for events that occurred in 1997. The fourth NOV, was for lead exceedances on October 31 and November 1, 1997. The fifth NOV was for four different pH exceedances in December 1997, although these exceedances were considered to be part of the pattern of pH exceedances discussed in the third NOV (October). LWRP permit exceedances and corrective measures are summarized in **Table 2-10** and discussed in detail in Chapter 6.

Table 2-10. Summary of compliance with LWRP permit limits for discharges to the sanitary sewer.

Permit No.	Exceedance	Date(s) exceeded	Description–solution
1250	Low pH	2/12 8/21 11/21 12/5 12/15 12/19 12/24	Continue investigating for sources and processes; provide enhanced education to the Laboratory's population regarding proper disposal of wastewater; short-term traceback; and install engineering control to contain all low-pH material.
	High pH[(a)]	2/21 4/7	Investigate for sources and provide enhanced education to the LLNL population regarding proper disposal of wastewater.
	Silver	2/5	Review waste disposal procedures for photoprocessor operations. Further educate LLNL population about proper disposal of wastewater.
	Mercury	7/4	Examine existing potential sources for mercury-bearing materials; identify new laboratory processes that may use or mobilize mercury; examine retention tank release records; and conduct a study to assess potential links between sewer line cleaning activities and levels of metals in LLNL effluent.
	Lead	10/31 11/1	No activities suggested or required by the LWRP.
1510G	None	None	None

[a] LWRP chose not to enforce these exceedances because they did not exceed the duration criteria of 40 CFR 401.17 and this type of exceedance is not addressed in 40 CFR 403.5.

In 1996, LLNL continued to seek an EPA exemption from continued compliance with federal Categorical Standards, 40 CFR 403.6B, because of the belief that the categorical wastewater standards were not written or intended for research and development facilities. The LWRP suspended the requirements for self-monitoring of categorical processes through 1996 while the applicability of the categorical standards was evaluated. With the renewal of permit number 1250 (96–97), LWRP and EPA determined LLNL was not eligible for the exemption. However, the permit renewal resulted in a reduced number of processes subject to categorical requirements. Self-monitoring of these processes was reinstituted in 1997, as required in the permit.

At LLNL's request, the LWRP combined the terms of 1996 permits 1508G and 1510G, for discharge of sewerable waste from TFF and for discharges from sitewide treatability studies, into a single 1997 sitewide treatability permit, 1510G. Discharges to sanitary sewer under 1510G (97) are monitored as they occur and reported annually to the LWRP. These self-monitoring programs and the associated analytical results documenting compliance with the self-monitoring provisions of the permit are detailed in Chapter 6. In 1997, LLNL achieved 100% compliance with the permit limits of 1510G.

The LWRP toured the abrasive (water) machining operation in Buildings 321 and 341 on February 4, 1997. Also on February 4, the LWRP conducted a general inspection of Building 432 operations. On October 1, 2, and 16, LWRP collected split samples of site effluent at Building 196 as part of the annual compliance sampling. LWRP staff also inspected ground water treatment facilities on October 2, 1997. On November 25, LWRP collected categorical process samples from abrasive (water) jet machines and semiconductor processes in Buildings 321 and 153, respectively. Results of LWRP inspections are summarized in **Table 2-8**.

Streambed Alteration Agreements and 404 Nationwide Permits

California Department of Fish and Game (CDFG) issued three streambed alteration agreements for construction and maintenance projects within arroyos at the Livermore site during 1997 (see **Table 2-11**). The Fish and Game Warden made a site visit to Arroyos Las Positas and Seco prior to issuing two of the steambed alteration agreements. One of these projects was also subject to Clean Water Act Section 404 permitting requirements and was covered by Army Corps of Engineers (ACOE) nationwide permits. The ACOE project manager and two ACOE archeologists visited Arroyo Seco when LLNL uncovered an archeological site while stabilizing the bank. The San Francisco Bay RWQCB issued a waiver from 401 Water Quality Certification for the project covered by a nationwide permit. See **Table 2-8** for a summary of the inspections.

Table 2-11. Summary of streambed alteration agreements and 404 nationwide permits.

Project	Location	Agency	Date submitted
Bank stabilization	Arroyo Seco	CDFG 401 Waiver 404 Nationwide permit 13	5/29/97 5/29/97 5/29/97
Vegetation cutting (non-wetland)	Arroyo Las Positas	CDFG	5/29/97
Vegetation cutting (wetland)	Arroyo Las Positas	CDFG	7/30/97
Maintenance (five-year agreement)	Site 300 drainage culverts	CDFG	1995

At Site 300, LLNL continued to operate under a five-year CDFG streambed alteration agreement issued in 1995 for maintenance of drainage channels.

Injection Wells

LLNL continues to operate injection wells registered with EPA at Site 300. LLNL has 32 active and 20 inactive Class V injection wells at Site 300. The majority of the active injection wells are sanitary septic systems and percolation pits receiving small volumes of wastewater from equipment such as boilers and cooling towers.

Spill Prevention Control and Countermeasures Plan

No significant changes were made in 1997 to the technology or practices documented in the Spill Control and Countermeasures Plan (Campbell 1995).

Tank Management

LLNL manages its underground storage tanks (USTs) and aboveground storage tanks (ASTs) through the use of underground tank permits, monitoring programs, operational plans, closure and leak documentation, and inspections. These topics are discussed in the following sections.

Tank Systems

At LLNL, underground tanks contain diesel fuel, gasoline, waste oil, and process wastewater; aboveground tanks contain diesel fuel, insulating oil, and process wastewater. Some of the wastewater systems are a combination of underground storage tanks and aboveground storage tanks. **Table 2-12** tabulates the status of the Livermore site and Site 300 tanks as of December 31, 1997.

Upon completion of closure activities, closure reports for underground hazardous product, hazardous waste, and mixed waste USTs must be submitted to the regulatory agencies for review and approval. (A mixed waste UST stores waste that has the characteristics of both hazardous and radioactive waste.) Three closure reports for hazardous product and mixed waste USTs were submitted to the Alameda County Health Care Services Agency for review in 1997. These are awaiting approval.

Table 2-12. Status of in-service tanks, December 31, 1997.

Tank type	Livermore site			Site 300		
	Permitted	Permits not required	Total	Permitted	Permits not required	Total
Underground storage tanks						
Diesel fuel	7	0	7	4	0	4
Gasoline	2	0	2	1	0	1
Waste oil	1	0	1	0	0	0
Process wastewater	3	50	53	0	10	10
Subtotal	**13**	**50**	**63**	**5**	**10**	**15**
Aboveground storage tanks						
Diesel fuel	0	25	25	0	7	7
Insulating oil	0	8	8	0	4	4
Process wastewater	6 [(a)]	58	64	0	10	10
Subtotal	**6**	**91**	**97**	**0**	**21**	**21**
TOTAL	**19**	**141**	**160**	**5**	**31**	**36**

a These six tanks are located at the LLNL Treatment, Storage, and Disposal Facility and are operated under interim status as part of the RCRA Part B permit application.

Two closure plans were completed in 1997. These closure plans were prepared for aboveground hazardous-waste tank systems.

Tank Upgrade Project

In 1992, LLNL began to upgrade or close wastewater retention tanks (for nonhazardous, hazardous, mixed, and radioactive waste) and product retention tanks (for petroleum products) in accordance with existing local, state, and federal tank regulations, or to decrease the potential for environmental contamination as the result of a release from a tank or its appurtenances. Work has been completed to bring LLNL into compliance with California and federal requirements for underground storage tanks, one year ahead of the December 1998 deadline. As of December 1997, construction had been completed for 153 tanks and was in progress for four aboveground hazardous and mixed-waste tanks.

The latter four tanks, known as the Quad Tank System, are located in the Hazardous Waste Management Division facility at Building 514. The Quad Tank System will be used to collect and store hazardous and non-DTSC regulated radioactive wastewater generated by LLNL activities. The aboveground Quad Tanks, each having a 4600-gallon capacity, replace one 25,000-gallon aboveground tank at the same location.

Closure and Leak Documentation

Closure requirements for hazardous USTs include the preparation and approval of closure plans, quarterly reports if leaks have been identified, and a report upon completion of closure activities. The closure plans must include a detailed review of the uses of the tank, a sampling plan, a site plan, and other information to verify that no environmental contamination has occurred or, if it has occurred, to ensure its cleanup. Hazardous waste ASTs must also meet regulatory requirements for closure plans, field activities, and closure reports.

Inspections

For every installation and closure of hazardous waste, mixed waste, and hazardous product USTs, there is an inspection in which a representative from Alameda County Environmental Health Services (ACEHS) (for the Livermore site) or San Joaquin County Public Health Services (for Site 300) participates. Inspections are summarized in **Table 2-8**.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) provides the framework at the federal level for regulating the generation and management of solid wastes, including wastes designated as hazardous. Similarly, the California Hazardous Waste Control Act (HWCA) sets requirements for managing hazardous wastes in California. RCRA and HWCA also regulate hazardous waste treatment, storage, and disposal facilities, including permit requirements. Because RCRA program authorization was delegated to the State of California in 1992, LLNL now works solely with California Department of Toxic Substances Control (DTSC) on compliance issues and in obtaining hazardous waste permits.

Hazardous Waste Permits

Livermore Site

The Livermore site hazardous waste storage and treatment management units continued to operate under interim status provisions (ISD CA2890012584) while DTSC continued to review and consider the latest modification to the Livermore site Part B permit application. Waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction).

LLNL submitted a revised Part B application on June 28, 1996. This application includes some existing hazardous waste facilities as well as the proposed Decontamination and Waste Treatment Facility (DWTF), which will be constructed in order to consolidate, replace, upgrade, and augment existing LLNL waste management capabilities. The revised Part B application, if approved by DTSC, will provide a mechanism for LLNL to operate portions of the existing hazardous waste facilities under interim status until DWTF is permitted and fully functional. A revised Health Risk Assessment was developed to supplement the Part B application and was submitted to DTSC in February 1997 (Hall et al. 1997).

A public hearing was held on October 9, 1997, regarding the draft hazardous waste facility permit, including the proposed negative declaration for the facility. A number of comments were received at the public hearing and during the subsequent public comment period. Permit issues and responses to comments are being reviewed in consultation with DTSC.

In response to the shredder incident previously described in the National Emission Standards for Hazardous Air Pollutants Section of this chapter, Barbara Barry of DTSC visited LLNL on November 12, 1997, and February 5, 1998. Her investigation of the incident resulted in a Summary of Violations dated February 9, 1998. The shredder involved in the incident is undergoing formal interim status closure and will be permanently removed from service.

Immediately after the shredder incident occurred on July 2, 1997, LLNL filed an Occurrence Report (OR number SAN-LLNL-LLNL-1997-0038), as required by DOE Order 232.1. LLNL also appointed an accident committee, but this committee was disbanded when DOE/OAK established a Type B Accident Investigation Committee. The Committee issued their report, which included several Judgments of Need (JONs), on August 29, 1997. LLNL submitted an action plan responding to the JONs on October 31, 1997. The plan included 47 actions designed to prevent a recurrence of an incident of this type. LLNL also filed a Price-Anderson Amendments Act (PAAA) notification report on July 23, 1997. On March 9, 1998, LLNL received a Preliminary

Notice of Violation from DOE/HQ/EH-10, with fines totaling $159,375. The fines were waived because nonprofit Maintenance and Operations contractors are exempt from fines under the PAAA. As a result of high radiation contamination levels in the shredder area following the accident, LLNL has chosen to dispose of the shredder as radioactive waste rather than risk worker contamination during cleanup operations. Loss of shredding capability will result in the need to reschedule some milestones in place under the Federal Facilities Compliance Act that required some mixed-waste processing in the shredder.

During the period of March 17 through March 21, 1997, DTSC conducted a Compliance Evaluation Inspection of Livermore site hazardous waste storage and treatment facilities, waste accumulation areas, and satellite accumulation areas. DTSC reviewed the following types of records and documents: inspection logs, hazardous waste manifests, land disposal restriction notifications, stored waste inventory, hazardous waste container tracking system, hazardous waste hauling license, and interim status documents.

As a result of the inspection, DTSC issued a Summary of Violations dated April 4, 1997, including “Minor Violations/Notice to Comply” and “Minor Violations Corrected During the Inspection.” The “Minor Violations/Notice to Comply” pertained to the emergency response training of a larger number of environmental analysts. The “Minor Violations Corrected During the Inspection” pertained to the storage of lead acid batteries in a waste accumulation area without containment pallets and appropriate labeling. LLNL responded to the April 4 DTSC Summary of Violations by letter dated May 6, 1997.

In addition to the three violations noted during the inspection, issues regarding combined waste were raised. Combined waste is waste containing radioactive constituents in combination with constituents that are categorized as “hazardous” under California regulations, but not federal regulations. Negotiations continue with DTSC on a statewide issue of the regulatory status of “combined waste.” While this issue is under discussion, and until it is resolved, a Memorandum of Understanding between DTSC and DOE is in effect.

Site 300

The Site 300 Building 883 hazardous waste container storage area operates under the provisions of the Part B permit (Part B CA28990090002) issued by DTSC in November 1989 and renewed in May 1996. The renewed permit also authorized the construction and operation of the Explosives Waste Storage Facility (EWSF), which augments the storage capability at Site 300 by providing a separate dedicated facility to store explosives waste. The EWSF became operational in March 1998.

A new, open-burning, open-detonation facility called the Explosives Waste Treatment Facility (EWTF) was proposed for Site 300. The proposed facility will replace the existing Building 829 Open Burn Facility. A Part B permit application for the proposed EWTF was submitted to DTSC in May 1993 and last revised in September 1995. The Part B application was supplemented by an Environmental and Exposure Assessment (EEA) submitted in May 1993 and last revised in September 1996. The EWTF permit was issued on October 9, 1997. It is anticipated that the EWTF facility will be operational in September 1998.

The Building 829 Open Burn Facility for explosives waste continues to operate under a stipulation order issued by DTSC in September 1993. Upon completion and operation of the EWTF, the Building 829 Open Burn Facility will undergo formal interim status closure. A closure plan was submitted to DTSC in July 1993, and a revised plan submitted to DTSC in April 1997. The closure plan was approved by DTSC on October 9, 1997. The closure will involve removal of all equipment and capping and grading of the area, in compliance with regulatory requirements for in-situ closure of a hazardous waste unit. Closure of this facility is anticipated by October 1998.

An emergency permit was issued by DTSC on November 6, 1997, for the treatment of 600 lb of off-specification propellant. The material was burned in a single burn at the existing Building 829 Open Burn Facility. A subsequent summary report was filed with DTSC. Subsequent to the issuance of the emergency permit by DTSC, the San Joaquin Valley Unified Air Pollution Control District verbally notified LLNL on November 12, 1997, to stop all open burning operations. Air emissions from these burning activities are reported to the agencies by means of quarterly burn reports and daily burn notifications. This agency notification resulted in a letter dated January 14, 1998, indicating that the burning of waste explosives was prohibited, pending the results of a formal air permitting process or other administrative procedure.

On January 29, 1997, DTSC conducted a Focused Compliance Inspection of Site 300 hazardous waste storage and treatment facilities, waste accumulation areas, and satellite accumulation areas. The inspection resulted in an amended inspection report dated April 22, 1997, which asserted that the characterization and storage practices for “combined waste” were in violation of regulations. This issue is under discussion between DOE and DTSC as part of the Memorandum of Understanding discussed in the Livermore site portion of this Hazardous Waste Permit section.

Hazardous Waste Reports

Two Annual Facilities reports, one for the Livermore site and the other for Site 300, were completed and submitted to meet DTSC's adjusted June 30, 1997, deadline. They address 1996 waste handling information. The annual reports are required under 22 CCR 66264.75 and are on file at LLNL.

The biennial reports, *Hazardous Waste Report—Mainsite* and *Hazardous Waste Report—Site 300*, are required under 40 CFR 262.41, 264.75, and 265.75. These reports were completed and delivered to DTSC by the March 1, 1998, deadline. They address 1997 waste handling information.

Hazardous Waste Transport Registration

Transportation of hazardous waste over public roads (e.g., from one LLNL site to another) requires DTSC registration (22 CCR 66263.10). Conditions for registration may include annual inspections of transport vehicles and trailers by the California Highway Patrol (CHP), biennial terminal inspections, and special training and annual physical examinations for drivers. The registration was renewed by DTSC in November 1996.

The CHP in Alameda County opted to conduct a vehicle safety compliance check of eight vehicles assigned to the Livermore site. This inspection occurred on December 9–10, 1997. Seven violations requiring corrective actions were noted. However, the violations were perceived as minor as indicated by LLNL receiving a satisfactory "current terminal rating."

Waste Accumulation Areas

Beginning in January 1997, there were 38 waste accumulation areas (WAAs) at the Livermore site and one at the Livermore Airport. Consolidation efforts resulted in the closure of 13 WAAs at the Livermore site. The Livermore Airport WAA was also closed during July 1997. One temporary WAA was put into service at the Livermore site, leaving a total of 26 WAAs. Program representatives conducted formal inspections at least weekly at all WAAs to ensure they were operated in compliance with regulatory requirements. About 1600 formal WAA inspections were conducted at the Livermore site and 21 at the Livermore Airport WAA. In addition, EPD personnel conducted informal biweekly walkthroughs at all WAAs to assist programs in managing their

WAAs and wastes in compliance with state and federal regulatory requirements. EPD personnel performed 644 biweekly WAA walkthroughs at the Livermore site and 11 biweekly WAA walkthroughs at the Livermore Airport.

During 1997, there were two WAAs at Site 300. Program representatives conducted 104 formal inspections of these WAAs. EPD personnel performed 38 biweekly WAA walkthroughs at Site 300 during 1997.

Medical Waste

LLNL is registered with the Alameda County Environmental Health Services (ACEHS) as a generator of medical waste and has a treatment permit.

During an inspection of LLNL's medical waste generator and treatment facilities on September 10, 1997, an ACEHS inspector determined that there were no compliance issues and no violations were found.

Building Inspections

Formal, detailed building inspections for each LLNL facility are conducted based on a schedule established by the facility manager and the appropriate Environmental, Safety, and Health (ES&H) Team. During 1997, the ES&H teams conducted 148 formal building inspections at the Livermore site and 25 at Site 300. Building inspections include buildings, trailers, and tents. Twelve audits of Hazardous Waste Management (HWM) Division facilities at the Livermore site and 12 audits of the HWM container storage facility at Site 300 were conducted by EPD personnel. Informal walkthroughs of buildings and associated areas are conducted on an as-needed basis.

Site Evaluations Prior to Construction

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Record of Decision for the LLNL Livermore site requires that a preconstruction site evaluation be completed prior to any soil excavation at the Livermore site. The preconstruction site evaluation is conducted to determine if soil or rubble (concrete and asphalt) is contaminated. Soil is sampled and analyzed for potential radioactive or hazardous contamination. Depending on the analytical results, soil may be reused on site or disposed of according to established procedures.

Depending on the results of the initial preconstruction site evaluation, rubble may be either surveyed or analyzed for radioactivity. During 1997, soil and rubble were evaluated at 93 construction sites.

Federal Facility Compliance Act

LLNL is working with DOE to maintain compliance with the Site Treatment Plan (STP) that was signed in February 1997. LLNL is cooperating with off-site facilities to establish profiles and dispose of the waste in a timely manner. Since February 1997, over 5000 cubic feet of waste has been characterized and shipped off site for treatment and disposal, which allowed LLNL to reach five of its STP milestones.

Toxic Substances Control Act

In September 1997, EPA approved the receipt of small amounts of polychlorinated biphenyls (PCBs) at LLNL from off site for the purpose of conducting research and development on new treatment and disposal methods for PCBs.

National Environmental Policy Act

The National Environmental Policy Act (NEPA—42 U.S.C. 4321 et seq.) established federal policy for protecting environmental quality. The major method for achieving established NEPA goals is the requirement for preparing an Environmental Impact Statement (EIS) for any major federal or federally funded project that may have significant impact on the quality of the human environment. If the need for an EIS is not clear, or if the project does not meet DOE's criteria for requiring an EIS, an Environmental Assessment (EA) is prepared. A Finding Of No Significant Impact (FONSI) is issued when the EIS is determined to be unnecessary.

Certain groups of actions that do not have a significant effect on the environment either individually or cumulatively can be categorically excluded from a more in-depth NEPA review (i.e., preparation of either an EA or EIS). DOE NEPA implementing procedures (61 FR 36222) identify those categorical exclusions and the eligibility criteria for their application. If a proposed project does not clearly fit one of the exclusion categories, DOE determines which type of assessment document may be needed.

In 1997, no FONSIs for Environmental Assessments or Records of Decision (RODs) for EISs were issued by DOE pertaining to LLNL operations. Forty-five categorical exclusion applications were approved by DOE, and there were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under 10 CFR 1022.

California Environmental Quality Act

An Environmental Impact Report Addendum (EIR Addendum) for the Continued Operation of the Lawrence Livermore National Laboratory was prepared and used by the Regents of the University of California to support their decision to extend the contract with the DOE from October 1997 through September 2002. The Notice of Determination was issued September 19, 1997.

In November 1992, UC and LLNL made a commitment to implement 67 mitigation measures identified by the *1992 Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (U.S. Department of Energy and University of California 1992a and b) (1992 Sitewide EIS/EIR) and to provide annual reports on their implementation. The measures are being implemented in accordance with the approved 1992 Mitigation Monitoring and Reporting Program associated with that joint DOE/UC EIS/EIR. The fiscal year 1995 annual report was published in April 1997; the next annual report will cover fiscal year 1996 activities.

National Historic Preservation Act

The National Historic Preservation Act of 1966 (NHPA), as amended through 1992, requires federally operated and funded installations such as LLNL to balance agency missions with cultural values by integrating historic preservation into federal agency programs. Federal agencies must take into account the effects their projects may have on “historic properties” (cultural resources), and they must allow a reasonable time period for the Advisory Council on Historic Preservation (the Council) to comment.

LLNL has three significant types of cultural resources: (1) prehistoric; (2) historic (turn-of-the-century homesteading, ranching, and industrial); and (3) historic World War II and Cold War science and technology).

A draft Programmatic Agreement (PA) was developed by LLNL in consultation with DOE/OAK, the Council, and the California State Historic Preservation Office (SHPO) with the intention of initiating activities that will help LLNL implement applicable federal and state cultural resource laws and regulations. These activities include cultural overviews, development of theme and context for significance evaluation, research designs, archaeological site identification and evaluation methods, records and collection management. The activities will also generate needed data and methods in order to develop a Cultural Resource Management Plan (CRMP), the final objective of the PA. A stipulation of the PA is that the draft CRMP will be submitted to the California SHPO and the Advisory Council within four years of a signed PA. Another stipulation requires that an annual progress report be generated and submitted to the Council and the SHPO.

A plan was developed in 1997 for the acquisition of Global Positioning System equipment and computer Geographical Information System hardware and software. These will help create an efficient and economical means of collecting, storing, analyzing, and retrieving data.

LLNL is now beginning the second phase of the development and implementation program, which includes finalizing the PA and implementing the activities outlined in that document in order to develop a CRMP.

Endangered Species Acts and Sensitive Natural Resources

LLNL must meet the requirements of both the U.S. Endangered Species Act and the California Endangered Species Act as they pertain to endangered or threatened species and other species of special concern that may exist or are known to exist at the LLNL sites. For example, in implementing the 1992 Mitigation Monitoring and Reporting Program in 1997, biological assessment surveys were performed for special-status species at 83 LLNL project construction (ground disturbance) areas. Presence data for the San Joaquin kit fox (*Vulpes macrotis mutica*), American badger (*Taxidea taxus*), and Western burrowing owl (*Speotyto cunicularia*) were collected at each project location, and other applicable mitigation measures were implemented when required.

During 1997, no active San Joaquin kit fox dens were discovered, but 11 potential dens were found. Six occupied American badger dens were discovered, and 38 unoccupied dens were identified. Nine active burrowing owl dens were discovered (one at the Livermore site and eight at Site 300), and six potential dens were identified. In addition, two new populations of the federally threatened red-legged frog (*Rana aurora draytonii*) and one of the federal candidate species California tiger salamander (*Ambystoma tigrinum*) were found at wetlands locations at Site 300.

In 1997, red-legged frogs (*Rana aurora draytonii*) were also identified in the eastern portion of Arroyo Las Positas on the Livermore site. Measures to mitigate the potential for future impacts to the frogs are being developed with the U.S. Fish and Wildlife Service. Also at the Livermore site, two separate pairs of white-tailed kites (*Elanus lecurus*), a state-protected raptor, successfully nested and fledged young.

Two of the three known natural populations of the large-flowered fiddleneck (*Amsinckia grandiflora*), a federally listed endangered plant species, occur at Site 300. A portion of Site 300 has been designated as critical habitat for the plant.

LLNL is currently working with the U.S. Fish and Wildlife Service on continued monitoring of native and experimental Amsinckia populations, and to further develop habitat restoration and maintenance techniques. This will include continued investigations into the use of herbicides, controlled burns, and native bunch grass transplantation to reduce the amount of exotic grass cover.

In 1997, it was found that the numbers of fiddleneck plants in the two native populations had drastically declined; these populations contained only 17% of the number of plants observed in 1996. In addition, it is feared that the smaller of the two native populations was extirpated as a result of heavy rain runoff through the canyon where the population was located. This resulted in the bank containing the population being washed away. Only a single small senescent plant was observed in 1997. The number of fiddleneck plants observed in the experimental population was not significantly different from that observed in 1996.

The decline in the number of plants in the remaining native population was likely due to the increased exotic grass cover as a result of the heavy rains experienced during the winter. The experimental population had undergone significant restoration of native bunch grasses, which helped to maintain a lower amount of exotic grasses. Herbicide treatment of the native population will be conducted next year in an effort to reduce exotic grass cover.

At Site 300, two additional sensitive plant species were identified in 1997. The big tarplant (*Blepharazonia plumosa*), a California Native Plant Society “rare” plant, was found to be widely distributed within the grassland ecoregion. Also, a population of a plant not seen in California since 1950, the Diamond-petaled poppy (*Eschscholzia rhombipetala*), was identified in the southwestern portion of the site. One new stand of the blue elderberry bush (*Sambuscus mexicana*), a plant species that serves as habitat for the endangered valley elderberry longhorn beetle (*Desmocerus Californicus dimorphus*), was also identified at Site 300.

Paleontological Resources

During soil excavation for the National Ignition Facility (NIF) at the Livermore site, a molar from a 14,000-year-old mammoth was found at a depth of about 10 m below the surface. After this discovery, LLNL obtained an excavation permit from the Department of Interior and removed bones from the construction area that are to be prepared in 1998 for later presentation. The bones (including 11 ribs, 3 vertebrae, 1 humerus, 1.5 tusks, and a partial skull with palate, jawbone, and molars) will be accessioned into the U.C. Berkeley Museum of Paleontology collection and, most probably, displayed at LLNL in the future.

Environmental Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations, plus DOE Order 232.1, *Occurrence Reporting and Processing of Operations Information* and DOE Order 5484.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements.* DOE Order 232.1 provides guidelines to contractor facilities regarding categorization and reporting of environmental occurrences to DOE. DOE Order 232.1 divides occurrences into three categories: emergency, unusual and off-normal occurrences. That order refers to DOE Order 151.1, *Comprehensive Emergency Management System*, for the categorization of all emergencies.

The EPD response to environmental occurrences is part of the larger LLNL On-Site Emergency Response Organization that also includes representatives from Hazards Control (including the LLNL Fire Department), Health Services, Plant Engineering, Public Affairs, Safeguards and Security, and Site 300. In 1997, eleven environmental incidents were categorized as Off-Normal Occurrences and one as an Unusual Occurrence according to the DOE Order 232.1 Implementing Procedures. None of the environmental occurrences, summarized in **Table 2-13**, caused any adverse impact to the public or the environment. Agencies notified of these incidents included DOE, Alameda County Health Care Services Agency, San Joaquin County Public Health Services, San Francisco Bay RWQCB, Central Valley RWQCB, Office of Emergency Services, and DTSC.

Table 2-13. Tabulation of environmental occurrences reported under the Occurrence Reporting System, 1997.

Date[(a)]	Occurrence category	Description
Mar 18	Off-Normal	Approximately 22,500 gallons of potable water were discharged because of a break in a water line northwest of Building 490. The release was reported to the San Francisco Bay RWQCB as required in NPDES Permit No. CA0030023, WDR 95-174. A written report to outside agencies in a nonroutine format meets the requirements for an Off-Normal Occurrence. OR 1997-0017
Apr 3	Off-Normal	Under terms stipulated in LLNL's permit to discharge sanitary sewer wastewater to the Livermore Water Reclamation Plant (LWRP), LLNL reported two separate releases above permit limits to the LWRP. The first was a release of silver on February 5, 1997. The second was a release of low-pH material on February 12. On April 3, 1997, LLNL received a Notice of Violation (NOV) from the LWRP for violation of sanitary sewer permit discharge limits for silver and pH. Receipt of an NOV meets the requirements of an Off-Normal Occurrence. OR 1997-0021
Apr 4	Off-Normal	As a result of a regulatory inspection by the DTSC, LLNL was issued a Summary of Violations (SOV) for improper labeling of recyclable batteries and improper training documentation. Receiving an SOV meets the requirements for an Off-Normal Occurrence. OR 1997-0022
Apr 9	Off-Normal	As a result of a regulatory inspection by the DTSC at Site 300 on January 29, 1997, LLNL was issued an NOV for improper storage of 71 containers of California Combined Waste at Building 804. Receiving an NOV meets the requirements for an Off-Normal Occurrence. OR 1997-0024
Jul 8	Off-Normal	A drum containing spent carbon material, contaminated with halogenated solvents, was shipped off-site to a treatment, storage, and disposal facility (TSDF) without the proper labeling as required by the DOT. Errors made by the shipper in material descriptions meet the requirements of an Off-Normal Occurrence under the Transportation Section. OR 1997-0048
Aug 22	Off-Normal	A golden eagle was found electrocuted when, because of its wing span, it had simultaneously touched two circuits on a utility power line near Building 834 at Site 300. The golden eagle is a federally protected species and this incident was therefore reportable, in writing, to the U.S. Fish and Wildlife Services. Arrangements were made with the U.S. Fish and Wildlife Services to ship the bird carcass to Oregon for further evaluation. A written report to outside agencies in a nonroutine format meets the requirements for an Off-Normal Occurrence. OR 1997-0049
Sept 3	Unusual	During excavation work on the NIF site, several large capacitors were discovered. Initial cleanup activities began within 24 hours of discovery of the capacitors and contaminated soil. The California Office of Emergency Services was immediately notified. Notifications within four hours or less to an outside regulatory agency meet the requirements of an Unusual Occurrence. OR 1997-0054

Table 2-13. Tabulation of environmental occurrences reported under the Occurrence Reporting System, 1997 (concluded).

Date[(a)]	Occurrence category	Description
Oct 2	Off-Normal	Under terms stipulated in LLNL's permit to discharge sanitary sewer wastewater to the Livermore Water Reclamation Plant (LWRP), LLNL reported a finding of mercury above the permit limit to the LWRP. The July 4, 1997, daily composite sample had a mercury concentration of 0.017 mg/L. On October 2, 1997, LLNL received a Notice of Violation (NOV) from the LWRP for violation of the 0.01 mg/L permitted discharge limit for mercury. Receipt of an NOV meets the requirements of an Off-Normal Occurrence. OR 1997-0060
Oct 13	Off-Normal	Under terms stipulated in LLNL's permit to discharge sanitary sewer wastewater to the Livermore Water Reclamation Plant (LWRP), LLNL reported an August 21, 1997, release of sanitary sewer effluent with a pH below the permitted limit of 5.0 on October 10, 1997. LLNL received a Notice of Violation (NOV) from the LWRP for violation of the sanitary sewer permit discharge limit for pH. Receipt of an NOV meets the requirements of an Off-Normal Occurrence. OR 1997-0063
Nov 24	Off-Normal	A container of waste was shipped to a treatment, storage, and disposal facility (TSDF) as a nonhazardous DOT material. When the shipment arrived, the TSDF performed a random sample analysis for flashpoint. The waste was determined to be ignitable, making it a DOT hazardous material. Errors made by the shipper in material descriptions meet the requirements of an Off-Normal Occurrence under the Transportation Section. OR 1997-0068
Dec 18	Off-Normal	The labeling on a 55-gallon drum of hazardous waste shipped to a TSDF did not indicate the entire contents of the waste drum. The drum contained several aerosol cans. The DOT label indicated the incorrect Hazard Class. Errors made by the shipper in material descriptions meet the requirements of an Off-Normal Occurrence under the Transportation Section. OR 1998-0001
Dec 23	Off-Normal	A container was shipped and sampled for pH at the TSDF. The pH was 1; the labeling on the container was incorrect. Errors made by the shipper in material descriptions meet the requirements of an Off-Normal Occurrence under the Transportation Section. OR 1997-0073

[a] The date indicated is the date the occurrence was categorized, not the date of its discovery.

Contributing Authors Acknowledgment

Many authors significantly contributed to this large and diverse chapter. We acknowledge here the work of David Armstrong, Jamie Bennett, Richard Blake, Richard Brown, Winifred Burks-Houck, Tina Carlsen, Connie DeGrange, Bob Felicitas, Karen Folks, Gretchen Gallegos, Keith V. Gilbert, Allen Grayson, Robert Harrach, Steve Harris, Rick Henry, Rod Hollister, Bill Hoppes, Jennifer Larson, Saverio Mancieri, Sandra Mathews, Keith Otsuki, Judy Steenhoven, Michael Taffet, Charlotte Van Warmerdam, Robert Vellinger, Joseph Woods, Jim Woollett, Jr., Kathi Young, and Kenneth Zahn.

3

Environmental Program Information

Introduction

Lawrence Livermore National Laboratory is committed to operating in a manner that preserves the quality of the environment. The Environmental Protection Department (EPD) leads this effort in the areas of environmental compliance and accountability. This chapter begins with a description of LLNL's integrated Environmental, Safety, and Health (ES&H) Management System, and continues with the discussions of Work Smart Standards, missions, and activities of EPD and its three divisions. Performance measures (PMs) used by DOE to evaluate the Laboratory's environmental protection efforts are then summarized. The bulk of the chapter is devoted to an account of LLNL's activities and progress in waste minimization and pollution prevention in 1997. Following descriptions of current issues and actions in the environmental programs arena, this chapter concludes with a brief discussion of spill response and EPD environmental training.

Integrated Environmental, Safety, and Health Management System

Protecting people and the environment is the most important consideration in day-to-day operations at LLNL. Attention to environmental, safety, and health factors is fully integrated into the Laboratory's research programs and operational culture. This integrated management approach requires accountability at all levels of the organization, project planning with protection in mind, and excellence in program execution. The ES&H Program at LLNL employs a process of assessing hazards and the environmental implications of our work; designing and implementing standards-based methods intended to control risks; and complying with the applicable ES&H regulations. This process is implemented using a graded approach, which increases the level of risk management as the hazard increases. An overview of the Laboratory's ES&H Program and a general description of how the Laboratory manages ES&H activities can be found in *The Environmental, Safety, and Health Program at Lawrence Livermore National Laboratory* (LLNL 1996a).

In October 1996, the Department of Energy issued DOE Policy 450.4: Safety Management System Policy. This policy provides a formal, organized process whereby employees plan, assess, and improve safety in their work. In this policy statement the term “safety” is used comprehensively to include environment and health. The policy was developed taking into consideration various consensus management standards such as International Standards Organization (ISO) 14000, Voluntary Protection Program (VPP), and Recommendation 95-2 from the Defense Nuclear Facility Safety Board. Embracing ISO 14000 by using the major components of the standard, while not adopting it in total, allows flexibility in various management systems while not requiring adoption of a standard for adoption’s sake. This policy lets the field of ISO 14000 develop such that if documented cost benefits can be demonstrated (in a command and control environment), a facility could elect to utilize the standard in total through its integrated safety management system (ISMS). Integrated ES&H management systems are defined as having five functions: to define the scope of work, analyze hazards, develop and implement standards-based controls, perform work, and provide feedback and improvement. The current LLNL ES&H management process reflects requirements of these five functions. Therefore, to satisfy the DOE’s ISMS requirement, LLNL’s primary task will be to update our guidance documents and formalize the standard set through the Work Smart Standard Closure Process. Additionally, documentation of our ES&H management system will be updated to reflect the concepts defined in ISMS. Implementation of a fully documented ISMS is scheduled to begin in 1998.

Work Smart Standards

In 1997, LLNL and DOE’s Oakland Operations Office inaugurated a Work Smart Standards (WSS) process, whereby safety professionals from both organizations identify hazards and establish standards of operation appropriate for the particular work environment. WSS will improve both safety and the working relationship between the DOE and LLNL and are expected to become part of the DOE contract with the University of California. DOE made the use of an environmental, safety, and health management system a policy (DOE Policy 450.4), an acquisition regulation (48 CFR 970.5204-2), and a contract requirement.

The WSS process (DOE M450.3-1) requires an understanding of the work, an analysis of the hazards associated with the work, and the selection of standards from which hazards controls are developed. LLNL has traditionally identified and controlled hazards to protect the LLNL staff, the public, and the environment, but the WSS process differs from the past in that responsibility for selection of appropriate and necessary standards is in the hands of both the DOE field office and LLNL. This process empowers the Laboratory and local DOE staffs, through consensus, to focus on the work being performed and to select sitewide environmental, safety, and health standards that are based on the actual work being conducted and its associated hazards and threats to the environment. Significant progress has been made so far; work and associated hazards have been defined for practically all activities, and appropriate standards have been selected. Efforts are now under way to select additional requirements for management processes to better link project planning and execution with the standards providing protection to people and the environment.

Standards are approved at the management level closest to the work. Others cannot approve the set, require concurrence, or second-guess the standards selected. The LLNL Director and DOE Oakland Operations Office Manager will approve the final set of sitewide standards. Reaching agreement with DOE on new work-based standards will align the Laboratory with industry practice; establish common environmental, safety, and health expectations for DOE and the University of California; and facilitate the tailoring of requirements to streamline and increase the effectiveness of management at the Laboratory. Existing ES&H methodologies and documentation will support the completion of the process.

Meeting new expectations for integrated ES&H management at the Laboratory will take several years, but the selection of WSS is expected to be completed in 1998. The WSS approach coupled with enhanced, integrated management promises further safety improvements and lower costs.

Environmental Protection Department

The Environmental Protection Department (EPD) is the lead organization for environmental support to operations at LLNL. It is responsible for environmental monitoring, environmental regulatory compliance, environmental restoration, and hazardous waste management in support of the Laboratory's Programs. EPD prepares and maintains environmental plans and guidelines, provides environmental guidance and support to Laboratory personnel, informs management about pending changes in environmental regulations pertinent to LLNL, represents the Laboratory in day-to-day interactions with regulatory agencies, and assesses the effectiveness of pollution control programs.

EPD monitors air, water, soil, and foodstuff; evaluates possible contaminant sources; and models the impact of LLNL operations on humans and the environment. In 1997, 24,380 samples were taken from air, sewage, ground water, surface water, soil, sediments, vegetation, and foodstuff. Almost 263,000 analytes were tested. These numbers represent a slight increase in the number of samples taken and a slight decrease in the number of analytes tested, compared to 1996 values. The type of samples collected at a specific location depends on the site and the potential pollutants to be monitored; see the specific chapters of this report for discussions of each environmental medium.

A principal part of EPD's mission is to work with LLNL programs to ensure that operations are conducted in a manner that limits environmental impacts and is in compliance with regulatory guidelines. EPD helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; responds to emergencies in order to minimize and assess any impact on the environment and the public; and provides training programs to improve the ability of LLNL employees to comply with environmental regulations.

LLNL programs are supported by EPD's four Environmental Support Teams (ESTs). The ESTs are integrated into the Environmental, Safety and Health Teams (ES&H Teams) at the Laboratory through the Environmental Analyst who chairs the ESTs. Each EST includes representatives from environmental specialties within the Operations and Regulatory Affairs Division (ORAD), along with a field technician from the Hazardous Waste Management (HWM) Division. Some ESTs also include a representative from the Environmental Restoration Division (ERD), the ES&H Teams, or the organizations supported by the ESTs. These teams evaluate operations, determine potential environmental impacts, and provide guidance on environmental regulations and DOE orders for existing and proposed projects. ESTs assist programs in planning, implementing, and operating projects and in understanding and meeting their environmental obligations. When permits are obtained from regulatory agencies, ESTs aid the program in evaluating the permit conditions and implementing recordkeeping requirements.

Operations and Regulatory Affairs Division

ORAD currently consists of eight groups that specialize in environmental compliance and monitoring and provide laboratory programs with a wide range of information, data, and guidance to make more informed environmental decisions.

ORAD prepares the environmental permit applications and related documents for submittal to federal, state, and local agencies and provides the liaison between LLNL and regulatory agencies conducting inspections; tracks chemical inventories; prepares National Environmental Policy Act (NEPA) documents and conducts related field studies for DOE; oversees wetland protection and floodplain management requirements; coordinates cultural and wildlife resource protection and management; facilitates and provides support for the pollution prevention and recycling programs; teaches numerous environmental training courses; coordinates the tank environmental compliance program; conducts compliance and surveillance monitoring; and provides environmental impact modeling and analysis, risk assessment, and reporting.

ORAD also actively assists in responding to environmental emergencies such as spills. During normal working hours, an Environmental Analyst from the ORAD Environmental Operations Group responds to environmental emergencies and notifies a specially trained Environmental Duty Officer (EDO). EDOs are on duty 24 hours a day and coordinate with LLNL's ES&H Team and other first responders or environmental specialists.

Hazardous Waste Management Division

All hazardous, radioactive, and mixed wastes generated at LLNL facilities are managed by the Hazardous Waste Management (HWM) Division in accordance with state and federal requirements. HWM processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer.

As part of its waste management activities, HWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas (WAAs) located near the waste generator to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for shipment of waste meet the specifications of the U.S. Department of Transportation (DOT) and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. HWM prepares numerous reports, including the annual and biennial hazardous waste reports required by the state and federal environmental protection agencies (see Appendix C). HWM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans.

HWM meets regulations requiring the treatment and disposal of LLNL's mixed waste in accordance with the requirements of the Federal Facility Compliance Act. The schedule for this treatment is negotiated with the State of California and involves developing new on-site treatment options, as well as finding off-site alternatives.

HWM is responsible for implementing a program directed at eliminating the backlog of Legacy Waste (waste that is not presently certified for disposal). This effort includes a large characterization effort to identify all components of the waste, as well as a certification effort, which will provide the disposal site with appropriate documentation.

Environmental Restoration Division

The Environmental Restoration Division (ERD) was established to evaluate and remediate contaminated soil and ground water resulting from past hazardous materials handling and disposal and from leaks and spills that have occurred at the Livermore site and Site 300, both prior to and during LLNL operations. At both the Livermore site and Site 300, ERD investigates field sites to characterize the existence, extent, and impact of contamination. ERD evaluates and develops various remediation technologies, makes recommendations, and implements actions for site restoration. ERD is responsible for managing remedial activities, such as soil removal and ground water extraction, and for assisting in closing inactive facilities in a manner designed to prevent environmental contamination.

As part of its responsibility for CERCLA compliance issues, ERD plans, directs, and conducts assessments to determine both the impact of releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment. ERD is responsible for interacting with the community on these issues. Several public meetings are held each year as required in the ERD CERCLA Community Relations Plans. To comply with CERCLA ground water remedial actions at the Livermore site, ERD has to date designed, constructed, and operated five fixed ground water treatment facilities and associated pipeline networks and wells, seven portable ground water treatment units (PTUs), and two soil vapor extraction facilities (see Chapters 7 and 8). At Site 300, ERD has designed, constructed, and operated two soil vapor extraction facilities, and three ground water extraction and treatment facilities.

ERD is actively designing, testing, and applying innovative remediation and assessment technologies to contaminant problems at the Livermore site and Site 300. ERD provides the sampling and data management support for ground water surveillance and compliance monitoring activities.

Performance Measures Summary

Since 1992, the contract the University of California has to manage and operate LLNL for DOE has contained performance objectives, criteria, and measures. Four of these performance measures (PMs) evaluated LLNL's environmental protection activities in 1997. The status of these measures is described in this report at the location referenced in **Table 3-1**.

Table 3-1. DOE environmental protection performance measures.

PM designator	Performance measure	Location in this report
1.5.b	Radiation Dose to the Public Public radiation doses to the maximally exposed individual from DOE operations will be measured or calculated and controlled to assure that doses are kept as low as reasonably achievable.	Chapter 12: Radiological Dose Assessment; section on Radiological Doses from 1997 operations. Chapter 2: Compliance Summary section on National Emission Standards for Hazardous Air Pollutants.
1.5.f	Occupational Safety and Health Findings and Violations Hazards are recognized during Occupational Safety and Health assessments, and serious and imminent danger situations are appropriately mitigated.	Chapter 2: Compliance Summary, **Table 2-8**.
1.5.g	Process and Solid Waste Generation (Waste Reduction and Recycling) The Laboratory continues to progress towards meeting the DOE's pollution prevention goals for the year 2000.	This chapter, section on Waste Minimization/Pollution Prevention.
1.5.i	Environmental Releases The Laboratory controls occurrences of environmental releases exceeding regulatory or permitted levels imposed by local, state, or federal agencies.	Chapter 2: Compliance Summary, **Table 2-9**, **Table 2-12**.

In their evaluation of LLNL's fiscal year 1997 self-assessment, DOE and UC gave LLNL an average score of exceeding expectations for the environmental performance measures for the reporting period. Data for calendar year 1997 will be included in the annual self-assessment and evaluation conducted August through October 1998.

DOE Pollution Prevention Goals

The Secretary of Energy has committed the Department to the following Pollution Prevention (P2) goals, which are to be achieved throughout the complex by December 31, 1999, using 1993 as a baseline:

1. Reduce total releases and off-site transfers for treatment and disposal of Emergency Planning and Community Right-to-Know Act (EPCRA) 313 toxic chemicals from routine operations by 50%.
2. Reduce the generation of radioactive waste from routine operations by 50%.
3. Reduce the generation of low-level mixed waste from routine operations by 50%.
4. Reduce the generation of hazardous waste from routine operations by 50%.
5. Reduce the generation of sanitary waste (after recycling) from routine operations by 33%.
6. Divert 33% of sanitary waste from all operations for recycling.
7. Increase the affirmative procurement of Environmental Protection Agency (EPA)-designated recycled products to 100%.

Progress toward achieving these goals is reported annually to the Secretary of Energy in LLNL's *Annual Report on Waste Generation and Waste Minimization Progress*.

The DOE's *Pollution Prevention Program Plan 1996* (U.S. Department of Energy 1996b) establishes six immediate priorities, due to be implemented by fiscal year 1998, which will help DOE Headquarters, the Operations Offices, and the sites focus resources on the most critical aspects of DOE's P2 program.

The six priorities are to: (1) establish senior management commitment to P2 implementation, (2) set quantitative, site-specific waste reduction and recycling goals, (3) institute performance measures, (4) implement cost-saving P2 projects, (5) design P2 into new products, processes, and facilities, and (6) ensure that site programs comply with federal, state, and DOE requirements.

LLNL prepared a P2 Plan, which meets the requirements of (1) DOE Orders 5820.2A and 5400.1; (2) RCRA, Sections 3002(b) and 3005(h); and (3) Title 22 of the California Code of Regulations. This Plan is reviewed annually and updated every three years; it was last updated and submitted to the DOE in May 1997 (Celeste 1997). The Plan reviews past and current pollution prevention activities and states the objectives of LLNL's waste minimization and pollution prevention efforts.

The P2 Program at LLNL is an organized, comprehensive, and continuing effort to systematically reduce solid, hazardous, radioactive, and mixed-waste generation. The P2 Program is designed to eliminate or minimize pollutant releases to all environmental media from all aspects of the site's operations. These efforts help protect public health and the environment by reducing or eliminating waste management and compliance costs, resource usage, inventories and releases of hazardous chemicals, and civil and criminal liabilities under environmental laws.

In accordance with EPA guidelines and DOE policy, a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal) has been adopted and is applied to all types of waste.

Waste Minimization/Pollution Prevention

LLNL is required by the UC Contract performance measures 1.5.g to annually review its waste generation for P2 opportunities and to propose implementation projects. Previously, waste streams at LLNL were evaluated in terms of the total quantities of waste generated. However, the waste streams of greatest concern are not necessarily those having the largest volume. Each process that generates waste must be considered, as well as the individual characteristics of the components within each waste stream.

LLNL continues to use a weighted ranking system to better rank the waste streams and to improve the prioritization of waste minimization efforts. The methodology assigns to each waste stream three weighting factors in addition to a factor based on quantity of waste generated annually. The three additional weighting factors use the following criteria: cost, waste type (which includes compliance and liability considerations), and operational aspects (such as routine vs nonroutine). This is discussed in *A Comprehensive Opportunity Assessment for Pollution Prevention at Lawrence Livermore National Laboratory* (Celeste et al. 1997).

In general, the 20 waste stream components having the highest priority (ranked by summing the four weighting factors) are entirely different from the top 20 source codes ranked by quantity only. For example, transuranic waste (TRU)/TRU mixed and low-level wastes, which are problematic at LLNL, are now ranked as having the highest priority, though their relative quantities are somewhat low.

Routine waste generation by waste category, from 1993 through 1997, is shown in **Table 3-2**. In fall 1997, DOE/OAK expressed concern that the quantity of waste that LLNL reported for 1993 may not have been tracked and recorded as accurately as the waste quantities that were reported using criteria that was developed after 1993.

Additionally, since 1994, LLNL has reported the waste quantities using new, improved technologies and procedures. Waste volumes for the years 1994 through 1997 were plotted using regression analysis to estimate the amount of waste generated in 1993.

Those new values for the years 1993 to 1997 are shown in **Table 3-2**. The trend from 1993 on shows a dramatic reduction in all waste categories, which is the result of a proactive P2 program at LLNL.

Table 3-2. Waste generation totals, 1990 to 1997 (in tons).

Waste category	1993 (Baseline)	1994	1995	1996	1997
Low-level radioactive	256	181	136	91	68
Low-level mixed	34	26	36	23	21
Hazardous	628	368	368	360	240
Sanitary	2600	2246	2246	2001	2017
LLNL totals	3518	2821	2786	2475	2346

Table 3-3 presents the percent reductions for 1997 compared to the 1993 baseline. Decreases in radioactive and hazardous waste generation in 1997 have already met the 50% reduction goal for the performance measure.

Table 3-3. Waste reduction, 1997.

Waste category	Reduction 1997 vs 1993 (%)
Radioactive	73.4
Mixed	38.2
Hazardous	61.8
Sanitary	22.4

Nonhazardous Solid Waste Minimization

In 1997, LLNL sent 3795 tons of nonhazardous waste, including routine and nonroutine, (designated sanitary waste in the above tables) to a landfill. The routine portion was 2016 tons and the nonroutine portion was 1779 tons. The breakdown is shown in **Table 3-4**.

Table 3-4. Nonhazardous landfill totals (in tons) in 1997.

	1997 total
Routine	
Compacted	1958
Industrial (TWMS)[a]	58
Routine subtotal	2016
Nonroutine	
Construction demo (non-compacted)	1734
Industrial (TWMS)	45
Nonroutine subtotal	1713
LLNL total	3731

a TWMS is the acronym for the HWM's Total Waste Management System.

Diverted Waste

The total waste diverted from landfills in 1997 was 323,461 tons. The difference between this year's total and that for 1996 is predominantly due to an increase in soil reuse on site. The reuse of soil on site and soil that is used at the landfill for daily cover (317,122 tons total) has increased more than 25-fold over last year, and we continue to use asphalt as road base material at the landfill (3020 tons). The waste diversion summary is shown in **Table 3-5**.

Table 3-5. Waste diversion summary table for 1997.

Description	Cumulative 1997 total (tons)
Asphalt	3020
Batteries	35
Cardboard	108
Compost	516
Diverted soil	317,122
HWM recycled materials	63
Magazines/newspapers/phone books	6
Metals	1,980
Paper	313
Tires, scrap	39
Toner cartridges	7
Wood	252
LLNL diversion total	323,461

For 1997, the total of the diverted waste and nonhazardous waste sent to landfill was 327,256 tons. The recycling rate for nonhazardous waste is calculated by dividing the diverted waste by the total of the landfill plus the diverted waste total. This results in a recycling rate of 92% for the nonhazardous waste for 1997. This far exceeds the DOE-stated goal of achieving a 33% recycling rate of nonhazardous waste by December 31, 1999.

For LLNL's UC contract, the goal is to reduce the routine nonhazardous (compactible and industrial) waste (tons) by 33% by December 31, 1999. As shown in **Table 3-4**, LLNL generated 2016 tons of nonhazardous waste in 1997.

LLNL has been required by California Law to reduce nonhazardous solid waste by 50% between 1990 and 2000. Significant reductions have already been achieved; this waste stream has been reduced by 28% since 1990.

In fiscal year 1997, LLNL received a National DOE P2 award for its achievements in solid waste recycling of construction and demolition debris.

Source Reduction and Pollution Prevention

The Laboratory formally surveyed its operations for opportunities related to source reduction and pollution prevention in 1995. Annually, effective as of fiscal year 1996, the Laboratory will continue to survey on-site operations for opportunities to eliminate, reduce, recover, or recycle potential pollutants to all media, including air, water, soil, sediments, and biota.

Toxic Reporting Inventory Information

At LLNL only one chemical, Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane, also known as CFC 113), is tracked and reported as part of the Toxic Release Inventory for 1997. This reporting is required by the Emergency Planning and Community Right-to-Know Act. All other chemicals are in quantities below the threshold reporting levels or are in a form that does not require reporting.

Freon 113, which is used in parts cleaning operations and as a coolant or refrigerant, is an ozone depleting substance whose consumption and production is slated for elimination by the year 2000. For this reason, the replacement and recycling of Freon 113 is a high priority at LLNL.

By the end of 1997, Freon 113 had been replaced in all but one parts cleaning operation. Many Freon 113 cleaning operations were replaced with ultrasonic and aqueous cleaners. Additionally, other coolant and refrigerant options have been explored.

Implementing Cost-Saving Pollution Prevention (P2) Projects

Pollution Prevention Opportunity Assessments (PPOAs) are conducted before the implementation of Pollution Prevention (P2) projects. The purpose of PPOAs is to characterize waste streams and identify those P2 options that can be cost effectively implemented. After a process has been selected for evaluation, the PPOA team contacts program personnel for a series of information gathering meetings, including walkthroughs, demonstrations, brainstorming sessions, and individual discussions. Included in the LLNL PPOA methodology is a return-on-investment calculation and cost assessment of the options for all PPOAs. Results or recommendations are developed in cooperation with program personnel and are thus technically evaluated for cost, return on investment, technical feasibility, and feasibility of implementation.

The DOE provides competitively allocated funding to P2 projects through the High-Return-on-Investment P2 Program. This program encourages proposals for the implementation of P2 projects that provide a high return on investment through reducing waste and associated waste management costs. LLNL participates in this program to obtain funding for cost-effective P2 implementation projects. To date, High-Return-on-Investment projects worth over $2.5 million have been proposed to DOE, and LLNL has received over $1.9 million in funding for these projects. LLNL additionally uses return on investment calculations and estimates of project cost-effectiveness to prioritize P2 projects for resource allocation and implementation at the Laboratory.

Review of New Processes or Experiments

Many organizations at LLNL use a “front end” review process that applies to new programs, projects, or experiments that could have a significant impact on the environment. In this review process, the initial hazardous materials projected to be used are identified, and concentrations of both the starting materials and the wastes produced are estimated. The possibility for chemical substitution, process changes, and recycling is then addressed. If an opportunity for P2 is identified, the Pollution Prevention Group will assist the generator evaluate the options. Researchers and project managers are encouraged to implement alternatives that are less hazardous or nonhazardous.

In general, P2 activities are covered by the pertinent directorate's P2 Plan. New activities are reviewed to identify possible P2 techniques. Projects and experiments performed by LLNL are evaluated for P2 opportunities. All personnel are encouraged to implement reasonable P2 opportunities that have been identified.

Design for Environment

In general, any means of accomplishing the goal of minimizing environmental life cycle impacts can be thought of as an element of design for environment, a concept that involves developing an understanding of and consideration for minimizing environmental impact over the lifetime of a project, and mitigating potential environmental impacts by overlaying this understanding directly onto the design of the project. Design for environment is a fairly nascent field, with a number of methodologies and definitions. Federal facilities are now required, under Executive Order 12856, to apply life-cycle analysis and total cost accounting principles to the greatest extent practicable when estimating P2 opportunities. Both of these can be considered elements of a new federally funded facility. In addition, Executive Order 12873 requires federal facilities to implement P2 by giving preference to the purchase of environmentally preferable products. In light of these developments, traditional methods and tools employed for management and accounting may not be sufficient or effective enough in and of themselves to meet the requirements of Executive Order 12856.

The Pollution Prevention Group, in conjunction with the National Ignition Facility (NIF) project management, completed a design-for-environment evaluation of the opportunities within the NIF Project. Recommendations were made for focused studies and projects in the construction, operation, and design and development phases of the NIF project that will have the most immediate impact in areas of greatest concern to project management (such as P2, environmental compliance, and cost). Approximately 20 potential study areas were identified. Implementation of recycling programs in the construction of the NIF, the development of a Pollution Prevention Plan for the NIF, and implementation of aqueous cleaning concepts in the design for parts and optics cleaning are currently under way. The NIF Pollution Prevention Plan will include Pollution Prevention Opportunity Assessments (PPOAs) on the predicted waste streams identified in the Preliminary Environmental Impact Statement (PEIS). The PPOAs are aimed at developing waste minimization options prior to the operational phases of the NIF.

Additionally, P2 measures that are technically and economically practicable are being considered in the design of the Site 300 Contained Firing Facility (CFF). Lists from architectural information exchanges and from P2 design documents are provided to the CFF design team for evaluation. The CFF project has an individual designated as the P2 coordinator for the project.

Implementing P2 Employee Training and Awareness Programs

Pollution prevention awareness information, which covers all disciplines, is disseminated in documents such as the *Pollution Prevention Plan* (Celeste 1997) and *A Comprehensive Opportunity for Pollution Prevention at Lawrence Livermore National Laboratory* (Celeste et al. 1997); posters and videos at events such as Earth Day; training and orientation; conferences and workshops; membership on LLNL committees; and formal presentations to groups such as the Environmental Safety & Health (ES&H) Working Group's Environmental Subcommittee.

Pollution prevention awareness is promoted through *Newsline* (LLNL's weekly newspaper) articles and administrative memos. The Pollution Prevention Group has developed a Web site to electronically distribute P2 information and also prepares brochures that briefly describe the P2 program at LLNL.

The Pollution Prevention Group conducts monthly reviews of the HWM's Total Waste Management System (TWMS) database. This database tracks waste generation, and it affords the Pollution Prevention Group the opportunity to identify potential problem waste streams for each directorate and address issues in real time.

Current Return-on-Investment Projects

Some of the Pollution Prevention Opportunity Assessments led to the preparation of high return-on-investment P2 project proposals in 1997. Major return-on-investment projects that were completed, were ongoing projects, or began in 1997 are listed in **Table 3-6**.

Table 3-6. Return-on-investment projects in 1997.

Operation	Project
Completed or in progress	
Microwave digestion equipment	Replace acid-digestion methods
Technical Information Department digital photography equipment	Install digital imaging components
Photomicrographs, Building 321	Install electronic imaging system
Ultra-high vacuum	Remove low-particulate with nonhazardous solvents
Wet-chemistry photography for ETM	Install electronic imaging system to replace wet chemistry photography
Mobile nondestructive analysis waste sampling	Reduce number of samples collected
High explosives water recycling system	Install wastewater recycling systems for Site 300
Uranium cutting tools	Continue research on methods to produce high-quality machine cutting tools capable of dry machining
Spent garnet	Collect for reuse in on-site nonstructural concrete
Metal plating shop rinse water disposal	Replace with cold evaporator for rinse water recycling
Cooling towers modification	Modify to reduce sludge production
Freon 113 parts cleaning removal	Replaced with ultrasonic cleaning unit
Arc spark spectrograph	Replaced with laser ablation spectrograph
Funded in 1997	
Solvent-based parts washers	Replaced with aqueous-based small parts washers
Machine shops coolant	Installed with cold evaporators for coolant recycling

ChemTrack

ChemTrack, a computerized chemical inventory system, is an important tool for ensuring compliance with SARA Title III and California Business Plan reporting requirements and for improving the overall management of hazardous materials at LLNL. ChemTrack tracks chemical inventories at LLNL through the use of bar codes, laser scanners, hand-held bar code scanners, and customized software. ChemTrack enhances LLNL's ability to obtain the toxic release information necessary to complete SARA 313 submittals. ChemTrack currently has an inventory of approximately 175,000 chemical containers ranging from 210-L drums to gram-quantity vials.

In addition, ChemTrack includes a chemical locating service that allows LLNL researchers to find and share chemicals. This minimizes the need to purchase new chemicals, thereby reducing procurement costs and the generation of hazardous waste. ChemTrack data is used by various LLNL organizations to improve emergency response capabilities and management of Material Safety Data Sheets (MSDSs), to more closely track specific high-hazard chemicals and other regulated substances, and to screen selected LLNL facilities for preliminary hazard analyses.

Current Issues and Actions

Many current issues and actions are described in this report according to chapter subjects. This section lists several not covered elsewhere.

ATSDR Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency whose mission is to prevent exposure and adverse human health effects and diminished quality of life associated with exposure to hazardous substances from waste sites, unplanned releases, and other sources of pollution in the environment. As part of this mission, ATSDR is mandated by Congress to conduct Public Health Assessments (PHAs) at sites such as LLNL, that appear on the National Priorities List. In 1997, ATSDR conducted site team meetings to identify site-related health concerns for evaluation as part of the PHA review process. ATSDR worked with the California Department of Health Services to draft two health consultations related to Livermore site operations, which will likely be part of the final PHA for LLNL. The first draft health consultation report assessed concerns related to the discovery of plutonium at levels above background in Big Trees Park, Livermore. The second draft report assessed the potential impacts on water quality of the municipal water supply that serves the city of Livermore and identified private wells located in the vicinity of LLNL. Although neither draft report identified any health risks, each report made several recommendations for further action. LLNL is working with ATSDR to resolve comments on the reports and to identify appropriate follow-up activities.

Integrated Safety Management Evaluation of LLNL

Integrated Safety Management is an approach to safety management in which safety is systematically integrated into management and work practices at all levels so as to protect the public, workers, and the environment. The U.S. Department of Energy (DOE) Office of Oversight evaluated LLNL's system of Integrated Safety Management (ISM) in 1997. The review included the DOE Oakland Office (OAK) and its prime contractor, the University of California (UC). This evaluation was the most recent in a series of evaluations conducted at DOE facilities by DOE Headquarters. Overall, the evaluation team identified the successful features of LLNL's safety management system as well as pointing out several areas for improvement.

Between September and November of 1997, the 25-person evaluation team spent approximately 6 weeks at DOE Oakland and LLNL intensively reviewing safety management. The review included the Plutonium Facility, Hazardous Waste Management facility, and the National Ignition Facility construction project as well as topical areas such as radiation protection and chemical and explosive safety.

The Safety Management (SME) team found that DOE/OAK, LLNL, and UC had clearly defined safety and management policies and performance expectations at the top levels of the organization. All three are committed to implementing ISM and have effectively partnered to continuously improve safety performance. Many of the essential elements of safety management have been implemented, including clear roles and responsibilities, mechanisms for contractual and individual accountability, an appropriate balance between safety and mission-related priorities, and effective identification of requirements. The team reported that LLNL had a good model for facility management and a mature matrix-management system. They also noted that many initiatives are under way to improve safety. These elements of safety management are reflected in the safe conduct of many mission related activities and work.

The SME team found that four of the seven safety principles were being followed, two needed improved implementation, and one was borderline. No areas were identified as being significantly weak. Implementing policies, procedures, and work functions was the area requiring the most improvement. In particular, greater emphasis was needed in the planning and control of work at the worker level. Improvements in this area, as well as a strengthened commitment to safety at lower levels, were considered key to reducing injuries and accidents. The team also noted the need for improved procedures to ensure the timely classification and reporting of emergencies.

The three partners, LLNL, DOE/OAK, and UC, plan to build on existing safety program strengths while fully implementing ISM over the coming year. Employee input will be sought in developing the mechanisms necessary to improve injury/accident performance, and pilot programs will be used to demonstrate their effectiveness before LLNL-wide implementation. Additionally, tighter safety controls will be put into place for the authorization and oversight of work performed by subcontractors.

Miniature Optical Lair Explorer

In 1994, the Operations and Regulatory Affairs Division (ORAD) developed and began using the Miniature Optical Lair Explorer (MOLE) to perform biological assessment studies at Site 300. The MOLE is a miniature tracked vehicle with a tiny camera that allows scientists to investigate subterranean tunnel systems of special-status wildlife species to determine animal presence and numbers. At LLNL, surveys for the San Joaquin kit fox, burrowing owl, and American badger are done before startup of ground-disturbing activities in order to ensure their protection, if present.

The MOLE was used successfully at LLNL in 1997 to survey for the presence of several special-status species with subterranean habits: the burrowing owl, American badger, California tiger salamander, and California red-legged frog.

In addition, improvements were made to the MOLE, including head-mounted virtual display of the camera image and a reduction in field battery pack weight from 8 to 3 lb. Further development and use of the MOLE will continue in 1998.

Leaking Underground Fuel Tank Studies

In 1995, LLNL led a team of researchers from LLNL and four University of California campuses in a collaborative study of underground contamination from leaking underground fuel tanks (LUFTs). The study, performed for the California State Water Resources Control Board (SWRCB), found that once fuel leak sources have been removed, fuel contamination generally does not spread far from the leak site. Given time, naturally occurring microbes in the soil and ground water will usually break down most of the pollutants before they can reach a source of drinking water. On the basis of this study, the SWRCB is revising its overall ground water cleanup policy, ranking cleanup sites by their risk to drinking water sources, and selecting appropriate cleanup techniques based on risk.

One of the important recommendations of the study was to identify a series of LUFT demonstration sites and to form a panel of experts made up of scientific professionals from universities, private industry, and federal and state regulatory agencies. This panel would provide professional interpretations and recommendations regarding LUFT evaluations and closures at demonstration sites.

As a result of this recommendation, ten Department of Defense (DoD) sites were selected in 1996. Site selection was coordinated through the California Military Environmental Coordination Committee Water Process Action Team. Sites were selected to represent each branch of the military services with bases in California, as well as a number of Regional Water Quality Control Boards (RWQCBs) and the diverse hydrogeologic settings in California where fuel hydrocarbon contaminant cleanup problems occur. The sites selected and their corresponding RWQCB regions are: Army Presidio at San Francisco, San Francisco RWQCB; Barstow Marine Corps Logistic Center, Lahontan RWQCB; Camp Pendleton Marine Corps Base, San Diego RWQCB; Castle Air Force Base, Central Valley RWQCB; China Lake Naval Weapons Center, Lahontan RWQCB; El Toro Marine Corps Air Station, San Diego RWQCB, George Air Force Base, Lahontan RWQCB; Port Hueneme Naval Construction Battalion Center, Los Angeles RWQCB; Travis Air Force Base, San Francisco RWQCB; and Vandenberg Air Force Base, Central Coast RWQCB.

Recommendations will be made by the Expert Oversight Panel formed as part of the demonstration project for an appropriate risk-management strategy at each site and the set of actions needed to achieve site closure, based on the concept of developing conceptual models that identify potential hazards associated with sources, pathways, and receptors. The recommendations will also include site-specific findings regarding natural attenuation potential and discussion with regulators.

To date, all sites in the Demonstration Program have been reviewed and site specific recommendations submitted to each site. A Final Program Report is due to be released in August 1998.

As part of LLNL’s continuing leaking underground fuel tank studies, an 18-month study evaluating impacts of the fuel oxygenate, Methyl *tertiary*-butyl ether (MTBE) has been completed and submitted to the California State Water Resources Control Board. The study concluded that:

- MTBE is a frequent and widespread contaminant in shallow ground water throughout California. Of the 32,409 leaking underground fuel tank sites recognized in the state, hydrocarbons are known to have impacted ground water at 13,278. A minimum estimate of the number of MTBE-impacted sites in California is greater than 10,000.

- MTBE plumes in ground water behave differently from other semi-water-soluble fuel components such as benzene, toluene, ethylbenzene, and xylenes (BTEX).
- Evidence to date indicates that MTBE is not significantly biodegraded in ground water. Assuming resistance of MTBE to biodegradation, concentrations of dissolved MTBE in ground water will eventually diminish sufficiently to meet regulatory concentration goals because of dispersion, although the time it may take to diminish may be significantly longer than for the more biodegradable BTEX compounds.
- MTBE has the potential to impact regional ground water resources and may present a cumulative contamination hazard because of the chemical's apparent resistance to biodegradation and its mobility. With a compound that appears both ubiquitous and stable, water resource management on the regional scale will become increasingly important.
- Leak prevention is a critical requirement for the continued use of MTBE to ensure future protection of drinking water resources.

Initiative to Improve VOC Cleanup Process by Using Historical Case Analysis

The goal of this initiative is a nationwide historical case evaluation that uses a large number of cases to identify common volatile organic compound (VOC) release conditions that pose low risks and can be managed with minimal effort and cost, versus release conditions that pose higher risks and warrant larger expenditures of money. The key to this initiative is a cross-cutting evaluation of the large amount of VOC case data that is available.

As part of this initiative, two groups have been formed: a Working Task Force (WTF) and a Peer Review Panel (PeerRP). The WTF will focus on technical issues of historical VOC case data collection and analysis and prepare draft findings and conclusions based on the data analysis. The PeerRP will review key deliverables; raise technical issues; and review and comment on draft findings, conclusions, and any recommendations. WTF includes members from the DOE, DoD, U.S. Navy and Air Force, U.S. EPA, California Regional Water Quality Control Boards, and the Western Governors Association Working Group on Interstate Technology and Regulatory Cooperation.

Data collection continues, initial data analysis has begun, and the PeerRP and WTF are formed and are meeting regularly. Data collection should be complete by June 1998, findings and conclusions should be prepared by September 1998, and recommendations should be prepared by December 1998.

Spill Reporting

The federal government and the State of California have several distinct statutory and regulatory provisions that require responsible persons to report releases or threatened releases of hazardous materials or pollutants into the environment. DOE has also established various Orders that require reporting of incidents to DOE Headquarters. These provisions have varying requirements regarding the types of releases that must be reported, the timing of the report or notification (immediate and follow-up), the content of the report (e.g., source of the release, nature of the material, and the quantity released), and the particular agencies that must be notified. Many releases must be reported under more than one provision, and compliance with one provision will not necessarily satisfy another applicable provision.

Response to Spills and Other Environmental Emergencies

All spills and leaks (releases) that are potentially hazardous to the environment are investigated and evaluated. The release response process includes identifying the release, shutting off the source (if safe to do so), eliminating ignition sources, contacting appropriate emergency personnel, cordoning off the area containing the released material, absorbing and neutralizing the released material, assisting in cleanup, determining if a release must be reported to regulatory agencies, and verifying that cleanup (including decontaminating and replenishing spill equipment) is complete. Environmental analysts provide guidance to the programs on preventing spill recurrence.

To maximize efficient and effective emergency environmental response, EPD established a 7-days-a week, 24-hours-a-day, on-call rotational position entitled the Environmental Duty Officer (EDO). Specialized EDO training includes simulated accidents to provide the staff with the experience of working together to resolve environmental issues within the regulatory structure. The on-duty EDO can be reached by pager or cellular phone at any time.

During normal work hours, Laboratory employees report all environmental incidents to the Environmental Operations Group (EOG) environmental analyst assigned to support their program area. The EOG environmental analyst then notifies the on-duty EDO of the incident and together they determine applicable reporting requirements to local, state, and federal regulatory agencies and to the DOE. The EDO and the EOG environmental analyst also notify and consult with program management, and have 7-days-a-week, 24-hours-a-day access to the office of Laboratory Counsel for questions concerning regulatory reporting requirements.

During off-hours, Laboratory employees report all environmental incidents to the Fire Dispatcher, who, in turn, notifies the EDO and possibly the Fire Department. The EDO then calls out additional EPD support to the incident scene as necessary, and follows the same procedures as outlined above for normal work hours.

Environmental Training

Major efforts are ongoing to provide LLNL employees with training on environmental topics aimed at improved compliance. Training tasks address both specialized training for environmental professionals and training in a variety of environmental topics for employees at all levels throughout LLNL. Courses presented by EPD's Training Section are listed in **Table 3-7**.

Table 3-7. EPD training courses.

Hazardous Waste Generation and Certification	RCRA Facility Management
Hazardous Waste Generation and Certification Review	RCRA for EWSF
Emergency Response for Environmental Duty Officers	New Hire Orientation
Waste Retention Tank Management	Petroleum Product Storage Tank Management
Waste Accumulation Area Operations	Hazardous Waste Sampling
Hazardous Waste Transportation	Identification of Hazardous Material
Storm Water Pollution Prevention	Low-Level Waste Generation and Certification
National Environmental Policy Act (NEPA) Compliance	SARA/OSHA Refresher Training
Spill Prevention, Control and Countermeasure Training	SARA/OSHA Field Experience
TRU Waste Generation and Certification	Packaging and Shipping Operations
Placarding: Hazardous Waste Transport	Environmental Duty Officer Briefings
Radioactive Materials	Waste Management Unit OJT
Separation for Highway Transportation	Air Source Management

LLNL’s Other Environmental Programs

While EPD plays a central role, every directorate at LLNL is responsible for environmental compliance and minimizing the impacts of its operations. Several directorates have taken particularly noteworthy steps in this direction. These include the plans for Defense Nuclear Technologies Program’s Contained Firing Facility at Site 300 that will move explosive tests inside a facility where the debris is contained, the Laser Program’s efforts to design the National Ignition Facility to have minimal environmental impact, Engineering’s Metal Finishing Group’s efforts to reduce waste and substitute less hazardous chemicals in many of their processes, and Education Program’s efforts to enhance environmental education.

Integral to LLNL’s environmental research is the Environmental Programs Directorate that conducts multidisciplinary research to assess and mitigate environmental and human risk from natural and man-made hazards and to develop and demonstrate new tools and technologies for environmental restoration. This work includes studies in the design, analysis, and testing of advanced waste-treatment technologies; in-situ environmental remediation using natural and engineered processes; pathway, dosimetry, and risk analysis of radioactive and toxic substances; atmospheric dynamics; subsurface imaging and characterization; and seismic processes.

Contributing Authors Acknowledgment

Major contributors to this diverse chapter were John R. Celeste, Sabre J. Coleman, Winifred A. Burks-Houck, C. Susi Jackson, Constance E. DeGrange, David Rice, Stephanie S. Goodwin, David W. Short, and James S. Woollett, Jr.

4

Air Effluent Monitoring

Arthur H. Biermann
Paula J. Tate

Introduction

Lawrence Livermore National Laboratory performs continuous air effluent sampling of atmospheric discharge points at several facilities. Air effluent emissions from facility operations are assessed to evaluate compliance with local, state, and federal regulations and to ensure that human health and the environment are protected from hazardous and radioactive air emissions.

LLNL complies with local, state, and federal environmental air quality laws and DOE regulations. DOE Orders 5400.1, General Environmental Protection Program; and 5400.5, Radiation Protection of the Public and the Environment define standards for controlling exposures to the public from operations at DOE facilities. Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs), 40 Code of Federal Regulations (CFR) 61, requires the continuous monitoring of certain discharge points and the estimation of dose to the public resulting from operations at DOE facilities. Guidance on air effluent sampling is provided in the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (U.S. Department of Energy 1991), 40 CFR 60, and NESHAPs-cited ANSI standards. In general, LLNL analyzes for most constituents at levels that are far below regulatory standards in order to determine any environmental impact.

Assessment of air effluent emissions and resulting dose to the public is performed by monitoring emissions and / or evaluating potential emissions. Currently, the air effluent sampling program measures only radiological emissions. LLNL has operations with nonradiological discharges; however, permits for these operations are obtained through local agencies having enforcement authority for the Clean Air Act, and monitoring of the effluent is not required. The agencies with oversight for LLNL compliance with air regulations are EPA Region IX, the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) for Site 300.

Historically, monitoring of radionuclide air effluents at LLNL has been implemented according to the DOE ALARA (as low as reasonably achievable) policy. This policy is meant to ensure that DOE facilities have capabilities consistent with the types of operations to monitor routine and nonroutine radiological releases, so that the dose to members of the public can be assessed and so that doses are ALARA. In addition, the NESHAPs 40 CFR 61, Subpart H regulations require that monitoring of facility radiological air effluents must be performed if the potential off-site dose equivalent is greater than 1 μSv/y (0.1 mrem/y), as calculated using the EPA-mandated air dispersion dose model and assuming no emission control devices. For air discharge points that are monitored, the results of the monitoring provide the actual source term for modeling to ensure that the NESHAPs standard, 100 μSv/y (10 mrem/y) total site effective dose equivalent, is not exceeded. Discharges from operations that have the potential to release radionuclides but that are not monitored are also evaluated according to the NESHAPs regulations, and the corresponding doses are added to those obtained by modeling monitored emissions to determine radiological NESHAPs compliance.

Air effluent monitoring of atmospheric discharge points determines the actual radionuclide releases from individual facilities and processes during routine and nonroutine operations, confirms the operation of facility emission control systems, and can corroborate and aid in the resolution of air surveillance measurement results for the site. (The relationship can also work the other way as well—air surveillance measurements can corroborate effluent monitoring.) Measurements made by the air surveillance samplers located on and off site are reported in Chapter 5.

A variety of radioisotopes are used for research purposes at LLNL; these include uranium, transuranics, biomedical tracers, tritium, and mixed fission products. The major radionuclide released to the atmosphere from the Livermore site is tritium. In addition to effluent sampling for tritium, a number of facilities at the Livermore site have air effluent samplers to detect the release of uranium and transuranic aerosols. The air effluent sampling systems described in this chapter apply to stationary and point source discharges. Diffuse, or nonpoint sources, are also monitored to fulfill NESHAPs requirements. Sampling methods to evaluate LLNL diffuse sources are described in Chapter 5, Data Supplement. Summary data from these diffuse sources can be found in Chapter 5 of this volume.

Methods

Air effluent monitoring involves the extraction of a measured volume of air from the exhaust of the facility or process and subsequent collection of particles in the extracted volume by filters or of vapors by a collection medium. After collection, the various radionuclides in the sample are measured by appropriate analytical methods.

At the beginning of 1997, LLNL operated 103 radionuclide samplers on air exhausts at 9 facilities at the Livermore site (see **Figure 4-1**). These systems are listed in **Table 4-1** along with the analytes of interest, the type of sampler, and the number of samplers.

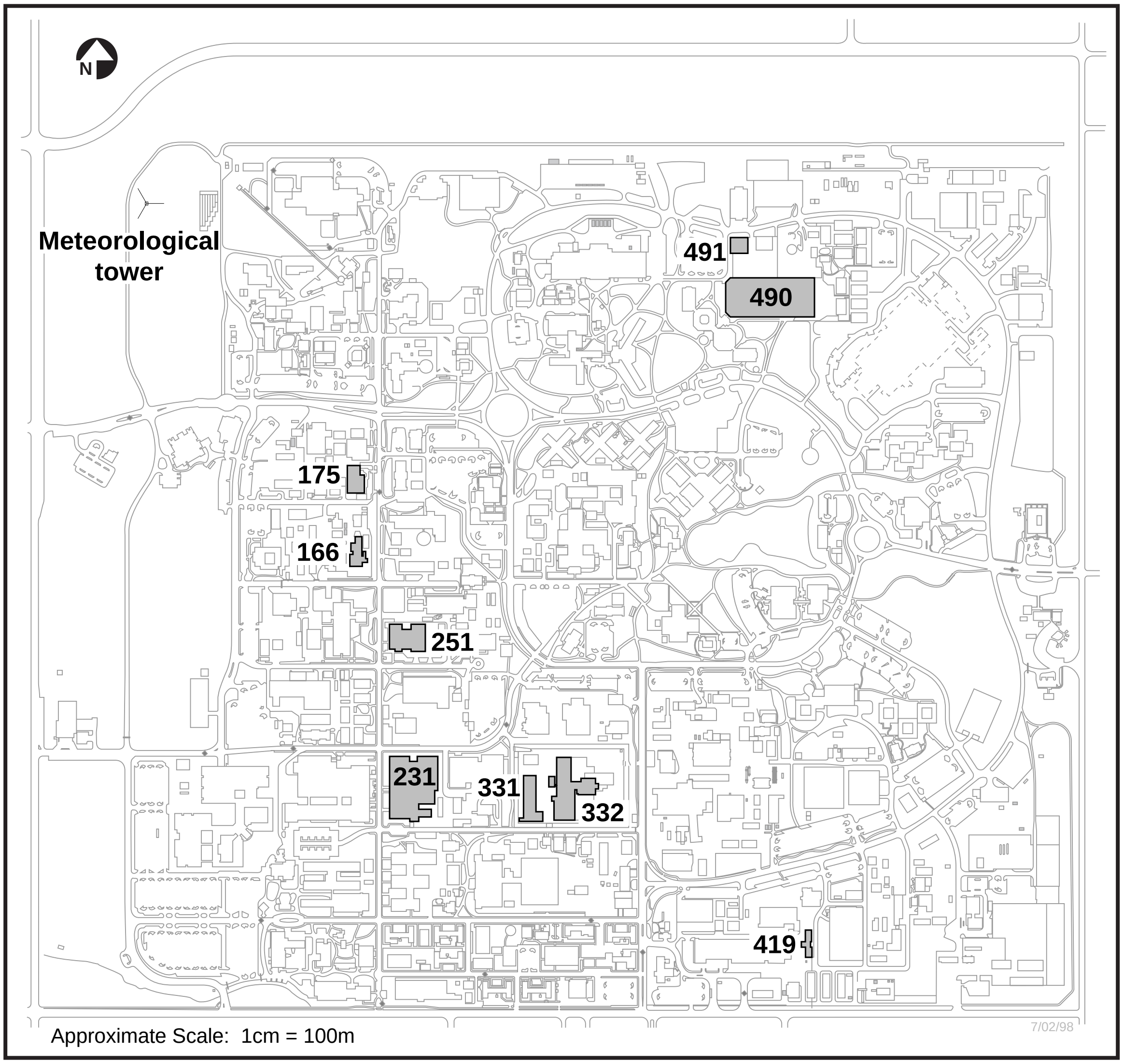

Figure 4-1. Buildings at the Livermore site having air monitoring systems for effluent gas streams during all or part of 1997 (see text).

LLNL reassesses the need for continuous monitoring on an annual basis and more often if warranted by new operations or changes in operations. During 1997, sampling at the locations in Buildings 166, 231, and 419 was discontinued. For Buildings 166 and 419 samplers were removed because the operations originally requiring sampling ceased. Continuous sampling at the Building 231 location was terminated because operations include the receipt, repackaging and shipping of only sealed or encapsulated sources. Therefore, normal operations are not a potential source of emissions and continuous sampling according to NESHAPs regulations is not required. Many of other sampling systems still in place (**Table 4-1**) are not required by regulation; however, LLNL continues to operate these systems as a best management practice.

Table 4-1. Air effluent sampling locations and systems.

Building	Facility	Analytes	Sampler type	Number of samplers
166	Pyrochemistry demonstration facility	Gross α, β on particles	Filter	1[a]
175	MARS	Gross α, β on particles	Filter	6
231	Vault	Gross α, β on particles	Filter	1[a]
251	Heavy elements			
	Unhardened area	Gross α, β on particles	Filter	44
	Hardened area	Gross α, β on particles	CAM[b]	4
		Gross α, β on particles	Filter	4
331	Tritium	Tritium	Ionization chamber[b]	4
		Gaseous tritium and tritiated water vapor	Molecular sieves	4
332	Plutonium	Gross α, β on particles	CAM[b]	12
		Gross α, β on particles	Filter	16
419	Decontamination	Gross α, β on particles	Filter	2[a]
490	Laser isotope separation	Gross α, β on particles	Filter	4
491	Laser isotope separation	Gross α, β on particles	Filter	1

Note: “CAM” denotes Eberline continuous air monitors.

a Sampling discontinued in 1997 due to programmatic changes and re-evaluation.

b Alarmed systems.

Sampling for particles containing radionuclides was conducted in eight of the facilities; sampling for tritium is conducted in one facility. All sampling systems operate continuously. Samples are collected weekly or biweekly depending on the facility. Most air samples for particulate emissions are extracted downstream of high-efficiency particulate air (HEPA) filters and prior to the discharge point to the atmosphere. Particles in the extracted air are collected on sample filters and analyzed for gross alpha and beta activity. Tritium is collected using molecular sieves. In addition to sample collection for environmental reporting, some facilities have real-time monitors (also listed in **Table 4-1**) at discharge points to provide faster notification in the event of a release of radioactivity. Analytical results from the continuous samplers are reported as a measured concentration per volume of air, or at the minimum detection concentration (MDC) when no activity is detected. In all cases, the MDC is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that are present or may be present in the sampled air. Further details of LLNL air effluent sampling systems are included in Chapter 4 of the *Environmental Monitoring Plan* (Tate et al. 1995).

Currently, nonradiological emissions (with the exception of beryllium) are permitted through the local air districts, and monitoring of them is not required. The California Air Toxics "Hot Spots" legislation requires facilities to prepare an air toxics emissions inventory and risk assessment, which LLNL has completed. Based on these data, the BAAQMD and the SJVUAPCD have ranked LLNL as a low-risk facility.

Measured Radioactive Air Emissions

This section discusses the radiological air emissions from facilities that have continuously monitored discharge points.

Livermore Site

In 1997, operations in the Tritium Facility (Building 331) released a total of 1.1×10^{13} Bq (300 Ci) of tritium. Of this, approximately 9.9×10^{12} Bq (270 Ci) were released as tritiated water (HTO). The remaining tritium released, 1.2×10^{12} Bq (30 Ci), was elemental tritium gas (HT). The highest single weekly stack emission from the facility was 7.6×10^{11} Bq (21 Ci), of which 5.0×10^{11} Bq (13.6 Ci) was tritiated water. Building 331 emissions continue to remain considerably lower than during the 1980's. **Figure 4-2** illustrates the emissions from the facility, both HTO and HT, since 1981. For 1997, emissions from Building 331 account for 97% of the estimated potential tritium emissions from the Livermore site.

For most of the continuously sampled discharge points having the potential for particulate radionuclide releases, sample results are below the MDC of the analysis. Sometimes as few as 1 to 4 samples (out of 25 to 50 samples per year) have concentrations greater than the MDC. Generally, these few samples having results above the MDC are only marginally above the MDC. Use of zero values for this type of data can be justified based on facility knowledge, the use of HEPA filters in all significant release pathways, and alpha-spectroscopy-based isotopic analyses of selected air-sampling filters. These isotopic analyses have demonstrated the presence of naturally occurring radionuclides, such as radon daughters, e.g., polonium, on air-sampling filters. In addition, because of exhaust configurations at some facilities, the monitoring systems sometimes sample air from the ambient atmosphere in addition to the HEPA-filtered air from facility operations, which gives rise to background atmospheric radioactivity being collected. Because of these considerations, the emissions from such facility operations are reported as zero. Furthermore, even if the

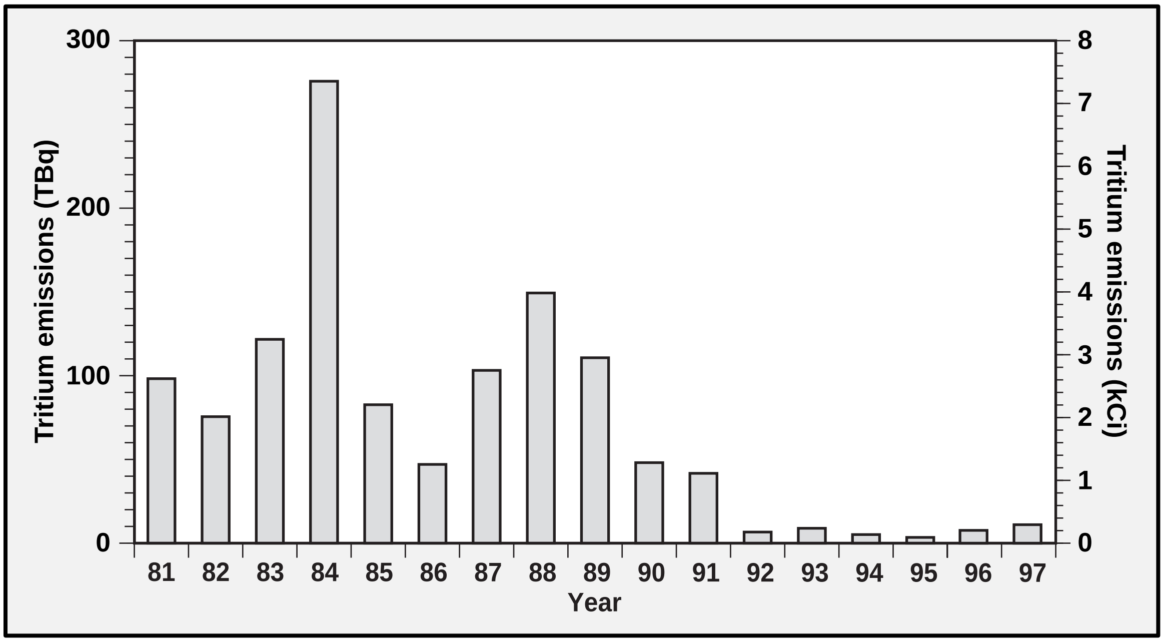

Figure 4-2. Tritium Facility emissions (HTO and HT) between 1981 and 1997.

MDC values were to be used in calculations of the emission estimates for these facilities, which would be an extremely conservative approach, the total dose to a member of the public attributable to LLNL activities would not be significantly affected.

In 1997, samples from four emission points at Building 251 (the unhardened area) yielded gross alpha results greater than the MDC on a significant number of the samples collected throughout the year. We use gross alpha as the primary indicator of potential emissions for operations such as those at Building 251 that involve the use of uranium and transuranic materials. Gross beta results are used as a further corroboration of those gross alpha results having concentrations above the MDC. The gross alpha and gross beta emissions for Building 251 were determined to be 6.0×10^3 Bq / y (1.6×10^{-7} Ci / y) and 3.9×10^4 Bq / y (1.1×10^{-6} Ci / y). Because of the number of samples with values above the MDC, we have taken a conservative approach and are reporting gross alpha and gross beta measurements as actual emissions.

The gross alpha monitoring concentrations for Building 251 ranged from -3.1×10^{-4} Bq / m^3 (-8.4×10^{-15} Ci / m$^{3)}$ to 3.7×10^{-5} Bq / m^3 (1.0×10^{-15} Ci / m^3). These activity concentrations do not differ significantly from the results of low-volume air surveillance samplers reported in Chapter 5. The Building 251 facility is in a standby, limited mode, of operation and emissions are not anticipated. So it is likely that emissions reported here for Building 251 are due to naturally occurring, or background, radioactivity, and to the facility exhaust configuration as previously mentioned. In any case, assessment of the gross alpha and gross beta emissions being reported here indicates the radiological dose is not a significant contributor to the dose to the public from all Livermore site operations.

Table 4-2 lists total radiological emissions as determined from the continuous sampling of facility exhausts for 1997. Radioactive effluent concentrations from individual discharge points at all monitored facilities are reported in Chapter 4, Data Supplement.

Table 4-2. Measured radiological air effluent emissions for the Livermore site, 1997.

Tritium			
Building	**Facility**	**Elemental, HT (Bq)**	**Tritiated water, HTO (Bq)**
331	Tritium	1.2×10^{12}	9.9×10^{12}
Gross alpha and gross beta			
Building	**Facility**	**Gross alpha (Bq)**	**Gross beta (Bq)**
251	Heavy Element	6.0×10^{3}	3.9×10^{4}

Site 300

Currently, there is no requirement for air effluent monitoring of facilities at Site 300. Air surveillance monitoring is performed for Site 300, and results are reported in Chapter 5.

All Potential Sources of Emissions

This section discusses the evaluation of all sources of radionuclide emissions to air at the Livermore site and Site 300. All discharge points having a potential to release radionuclides to the air are evaluated according to 40 CFR 61, Subpart H of the NESHAPs regulations. This evaluation, performed on an annual basis, uses radionuclide inventories and / or monitoring data along with EPA-accepted release factors for operations and EPA-suggested reduction factors for emission control devices to estimate the potential release for each individual discharge point. Potential emissions are those based upon the radionuclide inventories as distinguished from emissions based air effluent sampling. The evaluation is conducted to assess the dose to the public from all LLNL operations and the need for continuous sampling of individual discharge points.

For 1997, measured and potential emissions of radionuclides from 45 facilities were evaluated for their contribution of dose to a member of the public. The evaluation is based on estimated releases using radionuclide inventories specific to individual discharge points, physical state of the materials involved in the processes, and reductions due to emission control systems. The effective dose equivalent to a member of the public from specific operations at the Livermore site and Site 300 have been published in *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998a) and are summarized in Chapter 12 (Radiological Dose Assessment) of this report.

The radionuclide isotope responsible for the majority of the dose is tritium. Emissions from the Tritium Facility in the form of HTO account for 78% of the potential effective dose equivalent (EDE) to the maximally exposed member of the public from Livermore site (see Chapter 12). The dose from tritium gas is approximately 25,000 times lower than the dose from a comparable release of tritiated water. Therefore, the tritiated hydrogen gas emissions did not contribute significantly to the overall tritium dose. The other measured emissions shown in **Table 4-2** (Building 251) contribute negligibly to the EDE for the maximally exposed member of the public.

Many other isotopes are also used at the Livermore site and Site 300. However, simple comparison of the potential radioactivity emissions does not take into account atmospheric dispersion, dose, and the biological response to the isotope. The importance of other isotopes is assessed in Chapter 12 on risk assessment.

To determine the need for continuous sampling of a discharge point, all operations with the potential to contribute emissions to a discharge point were evaluated to determine if the dose to the maximally exposed member of the public exceeded 0.1 mrem for the calendar year. This evaluation is similar to that already discussed except no credit is allowed for emission control systems (according to the regulations). The evaluation for 1997 involved approximately 150 discharge points and/or discharges at the Livermore site and Site 300. No discharge points not presently having continuous sampling were found to require continuous sampling.

Nonradioactive Effluents

The Livermore site currently emits approximately 100 kg/day of criteria air pollutants (nitrogen oxides, sulfur oxides, particulate matter [PM-10], carbon monoxide, and lead). The largest sources of criteria pollutants from the Livermore site are surface coating operations, internal combustion engines, solvent operations, and, when grouped together, boilers (oil and natural gas fired).

The estimated releases from exempt and permitted sources of air pollutants at the Livermore site can be compared to daily releases of air pollutants for the entire Bay Area. For example, the total emissions of oxides of nitrogen released in the Bay Area for 1995 was approximately 4.8×10^5 kg / day compared to an estimate for LLNL releases of 59 kg / day for the Livermore site (0.012% of total Bay Area emissions). The BAAQMD estimate for reactive organic emissions was 5×10^5 kg / day, versus Livermore site's estimated releases of 37 kg / day (0.007% of total Bay Area emissions) in 1997. **Table 4-3** lists the estimated Livermore site 1997 total airborne releases for criteria pollutants.

Certain operations at Site 300 require permits from San Joaquin Valley Unified Air Pollution Control District. The total estimated air emissions during 1997 from operations (permitted and exempt air sources) at Site 300 are given in **Table 4-3**. Criteria sources at Site 300 include internal combustion engines, boilers, a gasoline dispensing operation, open burning, paint spray booths, drying ovens, and soil vapor extraction.

Table 4-3. Nonradioactive air emissions, Livermore site and Site 300, 1997.

Pollutant	Estimated releases (kg/day)	
	Livermore site	Site 300
Organics/volatile organics	37	1.1
Oxides of nitrogen	59	1.8
Carbon monoxide	10	0.41
Particulates (PM-10)	5.7	0.52
Oxides of sulfur	0.92	0.15

Environmental Impact

Measured radiological air emissions from the Livermore site operations for 1997 are well below levels that should cause concern for the environment or public health according to existing regulatory standards. The dose to the hypothetical maximally exposed member of the public due to the measured air emissions reported here (that is, due to emissions from monitored stacks) is 0.75 µSv / y (0.075 mrem / y), far below the NESHAPs standard of 100 µSv / y (10 mrem / y) and doses from naturally occurring radiation. Thus, the estimated radiological dose due to measured air emissions from LLNL operations is minimal. See **Table 12-2** in Chapter 12 for a summary of all doses, monitored or otherwise. Nonradioactive air effluents, which are also very small compared to emissions in surrounding areas, are well below standards and do not indicate threats to the environment or public health.

5

Air Monitoring

Paris E. Althouse
Paula J. Tate

Introduction

Air surveillance monitoring is performed to evaluate compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected from hazardous and radioactive air emissions. Federal environmental air quality laws and DOE regulations include 40 CFR 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act, and DOE Orders 5400.1, *General Environmental Protection Program,* and 5400.5, *Radiation Protection of the Public and the Environment*. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) provides the guidance for implementing DOE Orders 5400.1 and 5400.5. Other laws governing air quality include 22 CCR 67264.700 and 66265.710, Environmental and Compliance Monitoring, and the California Air Toxics "Hot Spots" Information and Assessment Act of 1987 (AB2588). In general, the constituents that LLNL analyzes (in order to determine environmental impact) are at levels far below the regulatory standards.

LLNL conducts surveillance monitoring of ambient air to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations, what the concentrations are, and what the trends are in the LLNL environs. In the air monitoring program, particles are collected on filters and vapor is chemically trapped on a collection medium. Concentrations of various airborne radionuclides (including particles and tritiated water vapor) and beryllium are measured at the Livermore site, Site 300, at off-site locations throughout the Livermore and Tracy Valleys. In addition, some point sources and diffuse, or nonpoint sources, are monitored to fulfill NESHAPs requirements (Gallegos et al. 1998a).

Methods

Several monitoring networks are established for surveillance of air particulates in the environs of LLNL and Site 300, as well as in the surrounding Livermore Valley and Tracy. The sampling locations for each monitoring network are listed in **Table 5-1**. All monitoring networks use continuously operating samplers located as shown in **Figures 5-1, 5-2,** and **5-3.** The radiological sampling networks utilize glass fiber filters, the high volume beryllium networks use cellulose filters, and the low volume network uses Millipore AW-19 filters.

Table 5-1. Sampling locations listed by monitoring network.

High volume radiological (glass fiber filters)	High volume beryllium (cellulose filters)	Low volume gross alpha and beta (millipore filters)	Tritium (silica gel)
Livermore site locations			
SALV CAFE VIS COW MET MESQ B531[(a)] CRED[(a)]	SALV CAFE VIS COW MET MESQ		SALV CAFE VIS COW MET MESQ POOL B292[(a)] B331[(a)] B514[(a)] B624[(a)]
Livermore Valley locations			
FCC FIRE HOSP CHUR[(b)] RRCH[(b)] PATT ZON7 TANK ALTA[(c)] LWRP		FCC HOSP	ZON7 ALTA FIRE XRDS VET HOSP
Site 300			
801E ECP EOBS GOLF NPS WCP WOBS	EOBS GOLF 801E		
Site 300 off site			
TFIR PRIM	TFIR		PRIM

a These locations are in areas of diffuse sources and are monitored to fulfill NESHAPs requirements.

b Location CHUR replaced RRCH in May of 1997.

c Location ALTA was removed from service in April 1997. It will be replaced by a new location in 1998.

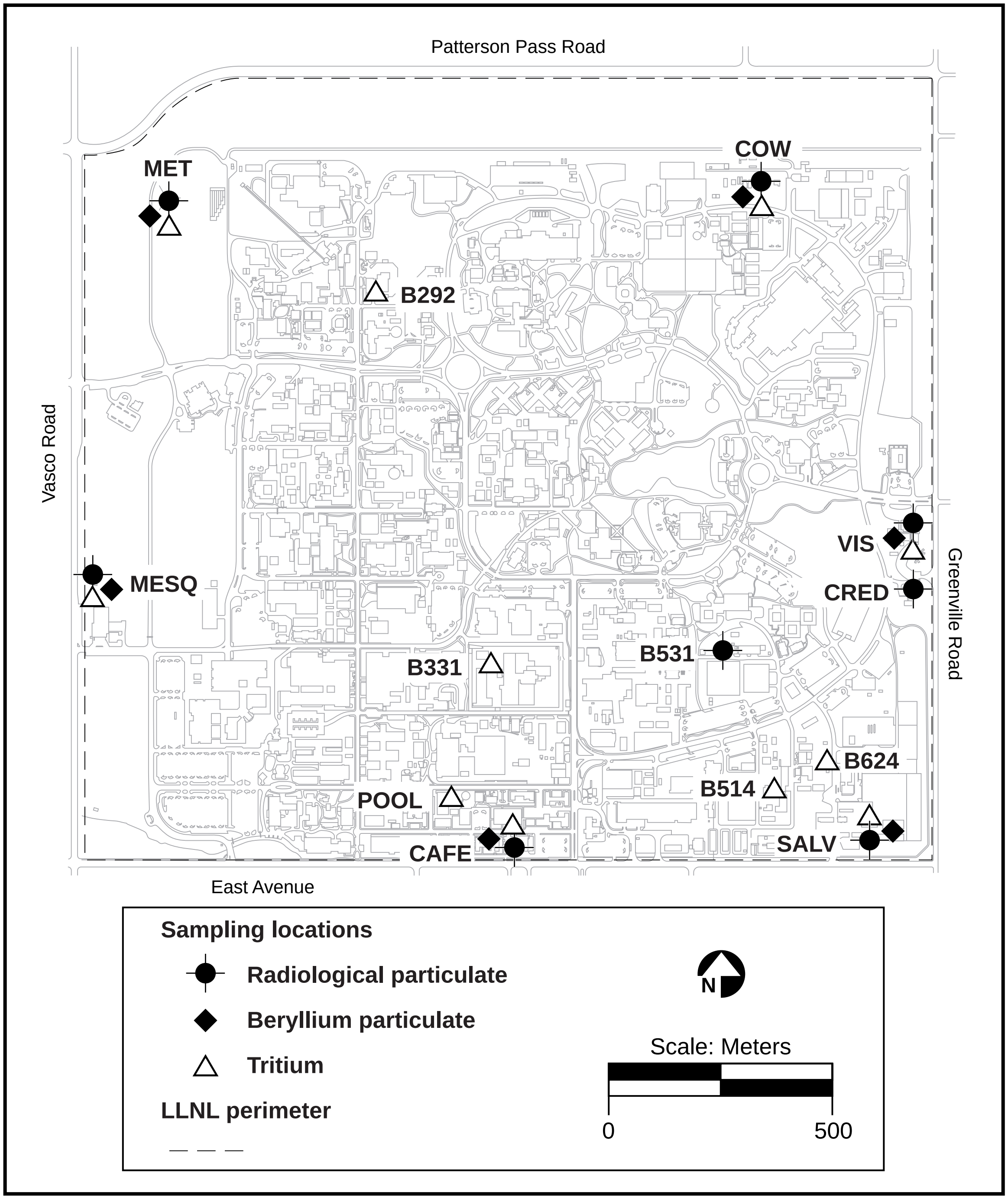

Figure 5-1. Air particulate and tritium sampling locations on the Livermore site, 1997.

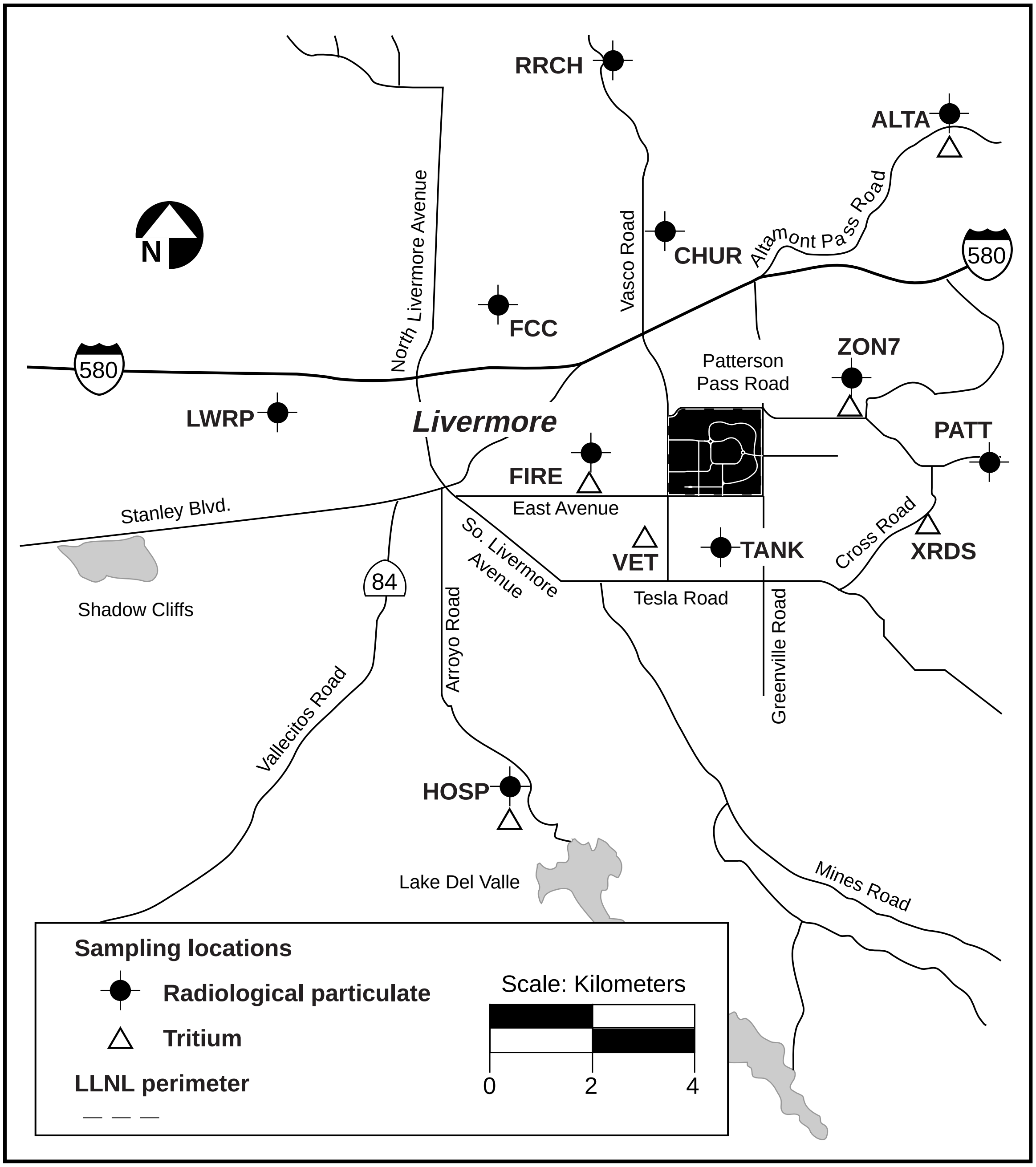

Figure 5-2. Air particulate and tritium sampling locations in the Livermore Valley, 1997.

The Livermore site radiological air particulate networks consist of six samplers at the perimeter. In addition, two areas of special interest (B531 and CRED) are monitored for plutonium only. The Livermore Valley network consists of air samplers located in all compass directions. For the purposes of data analysis, five samplers located in the least prevalent wind directions (FCC, FIRE, HOSP, RRCH, and CHUR) are considered to be

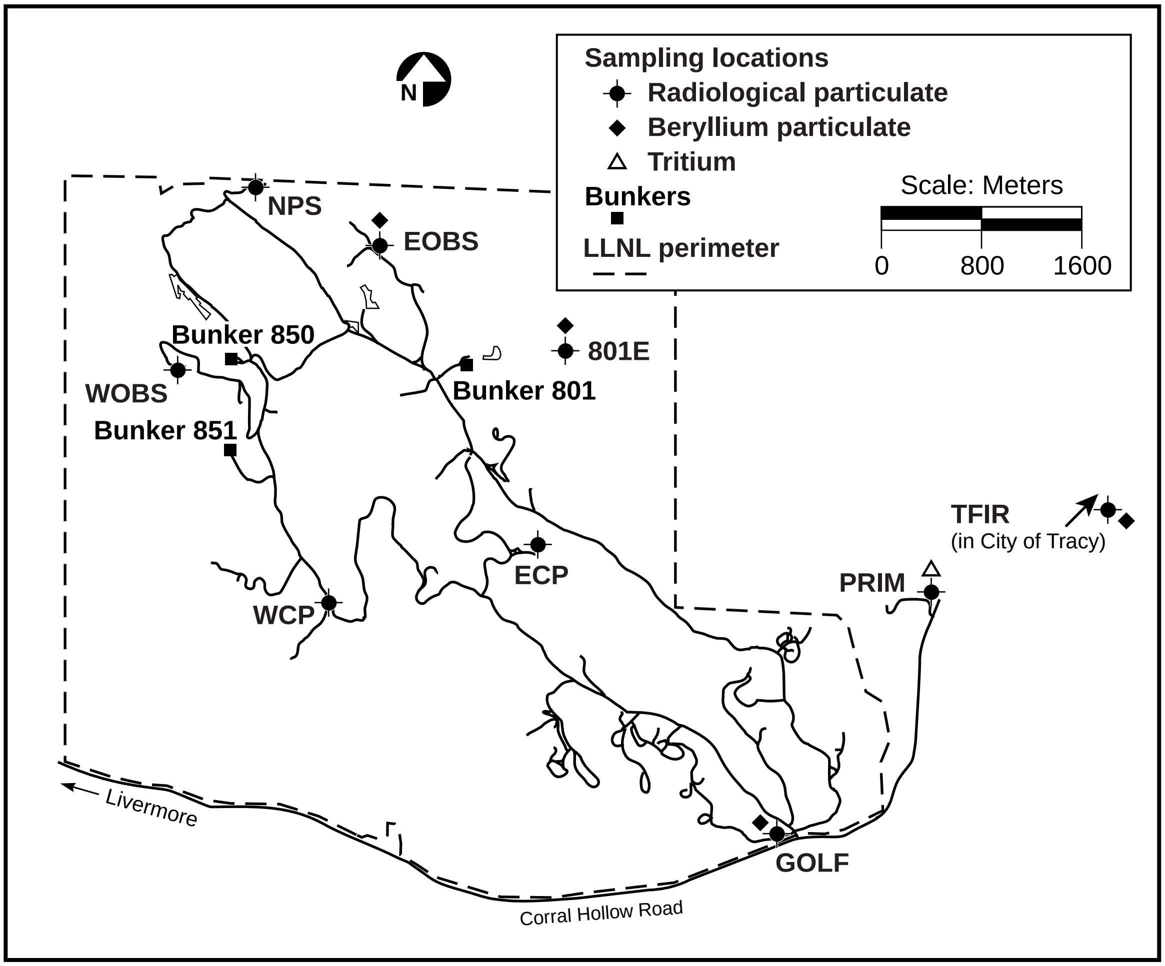

Figure 5-3. Air particulate and tritium sampling locations at Site 300, 1997.

upwind or representative of background locations and four samplers located in the most prevalent downwind directions (PATT, ZON7, TANK, and ALTA) are considered most likely to be impacted by Laboratory operations. An additional sampler is located in another area of special interest, the Livermore Water Reclamation Plant (LWRP), because of a plutonium release to the sanitary sewer system in 1967 with subsequent soil contamination and potential resuspension (see Results section below). A technical assessment of the beryllium monitoring locations at Site 300 was conducted in 1997. There is no requirement to sample for beryllium at Site 300; however, LLNL has decided to continue beryllium monitoring at three locations on site and at TFIR in the city of Tracy. These air samplers are positioned to provide reasonable probability that any significant concentration of radioactive particulate or beryllium effluents from LLNL operations will be detected should it occur. The geographical details of the particulate sampling locations are outlined in a procedure in Appendix A of the *Environmental Monitoring Plan* (Tate et al. 1995).

Two sampling systems were added in July 1997 as part of the new low-volume air surveillance sampling network. The samplers are situated at the FCC and HOSP locations, sites which are generally upwind of the Livermore site. The results are used to establish background levels of gross alpha and beta activity for direct comparison to results from the air effluent samplers. The sampling systems are very similar to the air effluent samplers used in facilities, including sampling system design, sampler operation, sample tracking, sample analysis, and processing of results.

LLNL also maintains 11 continuously operating airborne tritium samplers on the Livermore site (**Figure 5-1**), 6 samplers in the Livermore Valley (**Figure 5-2**), and 1 sampler near Site 300 (**Figure 5-3**). Four of the Livermore site locations (B331, B292, B514, and B624) monitor diffuse tritium emissions. The tritium sample locations are detailed in Appendix A of the *Environmental Monitoring Plan* (Tate et al. 1995).

Particulate filters (glass fiber, cellulose, and Millipore) are changed each week at all locations, and tritium samples are changed every two weeks. Duplicate quality control samplers are operated for 2 months in parallel with the permanent sampler at a given site, and samples are analyzed to confirm results.

As outlined in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991), gross alpha and gross beta air filter results are used as trend indicators; specific radionuclide analysis is done for plutonium, uranium, and gamma emitters. All analytical results are reported as a measured concentration per volume of air, or at the minimum detection limit (MDL) when no activity is detected. In all cases, the MDL is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that may be or are present in the air sample and for evaluating LLNL-induced environmental impacts. Particle size distributions are not determined because the estimated effective dose equivalent to the maximally exposed individual is well below the 0.01 mSv (1 mrem) allowable limit as discussed in the above mentioned *Environmental Regulatory Guide.* Further details of the surveillance monitoring methods are included in the Data Supplement, Chapter 5.

Results

This section discusses the air monitoring results at the Livermore site and at Site 300.

In April 1997, the filter media changed from cellulose to glass fiber for all radiological particulate sampling. Blank glass-fiber filters contain detectable amounts of some naturally occurring radiological isotopes. Of those radiological isotopes that LLNL monitors, detectable amounts of ^{235}U, ^{238}U, ^{40}K, ^{228}Ra, and ^{228}Th are found on the blank filters. A full investigation of the radioactive content on glass fiber filters used by LLNL is in progress. The measured concentrations of these isotopes were adjusted according to EPA procedures (EPA 1976). This procedure simply subtracts the appropriate blank filter content from the gross analytical result to obtain a corrected net result.

Livermore Site

Airborne Radioactivity

Table 5-2 summarizes the monthly gross alpha and gross beta results for the LLNL perimeter, Livermore Valley, and Site 300 sampling locations. Medians, interquartile ranges (IQR), and maximum values for each network are included. (See Data Supplement, Tables 5-1 and 5-2a and b for detailed location results for all high-volume networks for gross alpha and gross beta concentrations.) The monthly median gross alpha and gross beta concentrations are plotted in **Figures 5-4** and **5-5**, respectively. The gross beta results follow a similar pattern to previous year’s data. The gradual increase in beta activity throughout the summer is due to an increase in resuspension of soils that occurs during the dry season.

The gross alpha data are much more variable because of the nature of the standard analytical method capabilities, and most of the data are very close to the minimum detection limit of the method.

Typical gross alpha activity (median value) for the LLNL perimeter network is 1.6×10^{-11} Bq / mL (4.4×10^{-22} Ci / mL); for the upwind Livermore Valley stations the value is 1.4×10^{-11} Bq / mL (3.4×10^{-22} Ci / mL); and for the downwind Livermore Valley stations the value is 1.6×10^{-11} Bq / mL (4.4×10^{-22} Ci / mL). Negative values occur when the activity of the analytical background filters is higher than the activity on the filters being analyzed. Typical gross beta activity (median value) for the LLNL perimeter is 5.1×10^{-10} Bq / mL (1.4×10^{-20} Ci / mL); for the upwind Livermore Valley stations the value is 5.7×10^{-10} Bq / mL (1.4×10^{-20} Ci / mL); and for the downwind Livermore stations the value is 4.9×10^{-10} Bq / mL (1.3×10^{-20} Ci / mL). These values are similar to those obtained from previous monitoring data during the past several years. The primary sources of the alpha and beta activities are the naturally occurring radioisotopes of uranium and thorium, and any residual fallout from atmospheric weapons testing and the Chernobyl reactor accident in 1986.

Table 5-2. Gross alpha and gross beta in air particulate samples summarized by month, 1997.[a]

	Gross alpha (10^{-12} Bq/mL)			Gross beta (10^{-12} Bq/mL)		
	Median	**Interquartile range**	**Maximum**	**Median**	**Interquartile range**	**Maximum**
LLNL perimeter						
Jan	23.5	78.8	107	185	407	784
Feb	–4.74	49.6	85.1	278	146	412
Mar	28.8	66.9	138	297	220	605
Apr[b]	25.3	22.7	136	476	98.4	661
May	18.4	32.2	89.5	513	114	661
June	7.66	31.2	57.3	415	96.3	595
July	23.8	32.2	77.0	558	212	891
Aug	18.2	37.1	74.3	533	125	778
Sept	–0.422	36.0	40.9	726	364	1350
Oct	11.2	40.7	64.6	1090	672	1470
Nov	8.64	38.2	57.2	521	223	989
Dec	–11.5	24.6	69.8	856	324	1220
Livermore Valley upwind						
Jan	31.2	76.3	155	280	315	645
Feb	26.9	53.2	122	274	130	424
Mar	26.7	36.5	70.8	292	129	550
Apr[b]	16.5	32.2	89.0	450	87.3	637
May	22.6	30.8	83.0	578	147	636
June	0.477	35.5	33.0	417	58.1	505
July	21.9	26.7	52.8	567	163	727
Aug	17.5	33.7	83.5	524	170	736
Sept	–2.96	31.4	59.0	661	428	1270
Oct	17.4	32.4	37.1	1220	761	1550
Nov	–1.23	36.1	77.0	579	374	1060
Dec	–5.76	42.9	39.5	843	415	1330

Table 5-2. Gross alpha and gross beta in air particulate samples summarized by month, 1997[(a)] (concluded).

	Gross alpha (10^{-12} Bq/mL)			Gross beta (10^{-12} Bq/mL)		
	Median	**Interquartile range**	**Maximum**	**Median**	**Interquartile range**	**Maximum**
Livermore Valley downwind						
Jan	1.90	39.7	83.8	268	318	651
Feb	13.2	31.8	102	297	93.0	399
Mar	9.08	31.2	106	272	143	699
Apr[(b)]	20.9	18.5	42.4	497	63.3	587
May	17.6	43.2	71.2	564	116	713
June	7.23	17.6	45.1	421	31.7	550
July	22.1	24.7	70.6	553	192	846
Aug	30.8	20.5	50.0	499	127	657
Sept	–7.75	27.7	63.5	700	307	1210
Oct	21.7	25.6	96.5	922	845	1710
Nov	6.04	30.0	64.6	523	483	1080
Dec	15.4	31.7	83.0	814	374	1300
Site 300						
Jan	9.64	57.1	91.1	195	191	808
Feb	1.40	55.4	149	292	138	578
Mar	22.4	50.5	85.2	281	234	518
Apr[(b)]	20.1	28.5	65.6	496	115	614
May	37.5	32.7	101	643	131	910
June	10.7	21.3	58.5	507	101	671
July	39.3	35.2	97.2	706	185	1010
Aug	33.4	31.8	97.9	636	226	838
Sept	5.68	24.4	89.1	808	458	1310
Oct	21.3	31.7	85.0	884	766	1880
Nov	1.13	46.1	94.1	654	414	1260
Dec	-2.77	53.5	65.1	790	349	1800

a Negative values indicate that at least half of the samples had activity of the background greater than that of the sample.

b Filter media changed from cellulose to glass fiber. Samples from April through December were collected on glass fiber filters.

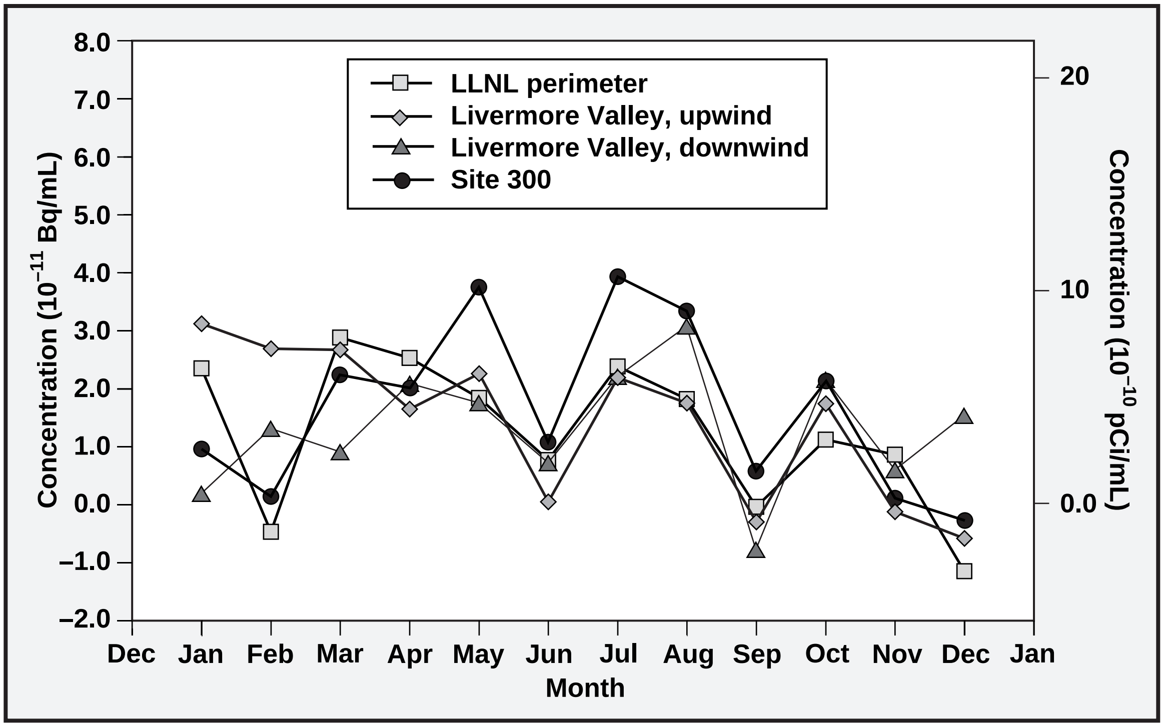

Figure 5-4. Monthly median gross alpha concentrations in particulate air samples from the LLNL perimeter, Livermore Valley and Site 300 sampling locations, 1997.

Gamma-emitting radionuclide concentrations in air that contribute to the activity in the Livermore site perimeter samples are summarized in **Table 5-3**. (See Data Supplement, Table 5-3 for monthly gamma data.) Of the nuclides tabulated, ^{7}Be, ^{40}K, ^{226}Ra, ^{228}Ra, and ^{228}Th occur naturally. The primary source of ^{137}Cs is long-term global fallout and fallout resuspension.

In addition to providing baseline data on global fallout, analysis of these radionuclides enables LLNL to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL. The Derived Concentration Guides (DCGs) for these radionuclides are also shown in **Table 5-3**. For air, DCGs specify the concentrations of radionuclides that could be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent (DOE Order 5400.5). (Chapter 12 on Radiological Dose Assessment provides an explanation of this and other units of dose.) Finally, the fraction of the DCGs is presented. These values demonstrate that levels of gamma activity present in air at the Livermore site perimeter are far below the DCGs. Air monitoring data are compared to the DOE DCG in 5400.5, and compliance with the EPA 100 μSv (10 mrem) standard (40 CFR 61) is demonstrated by modeling.

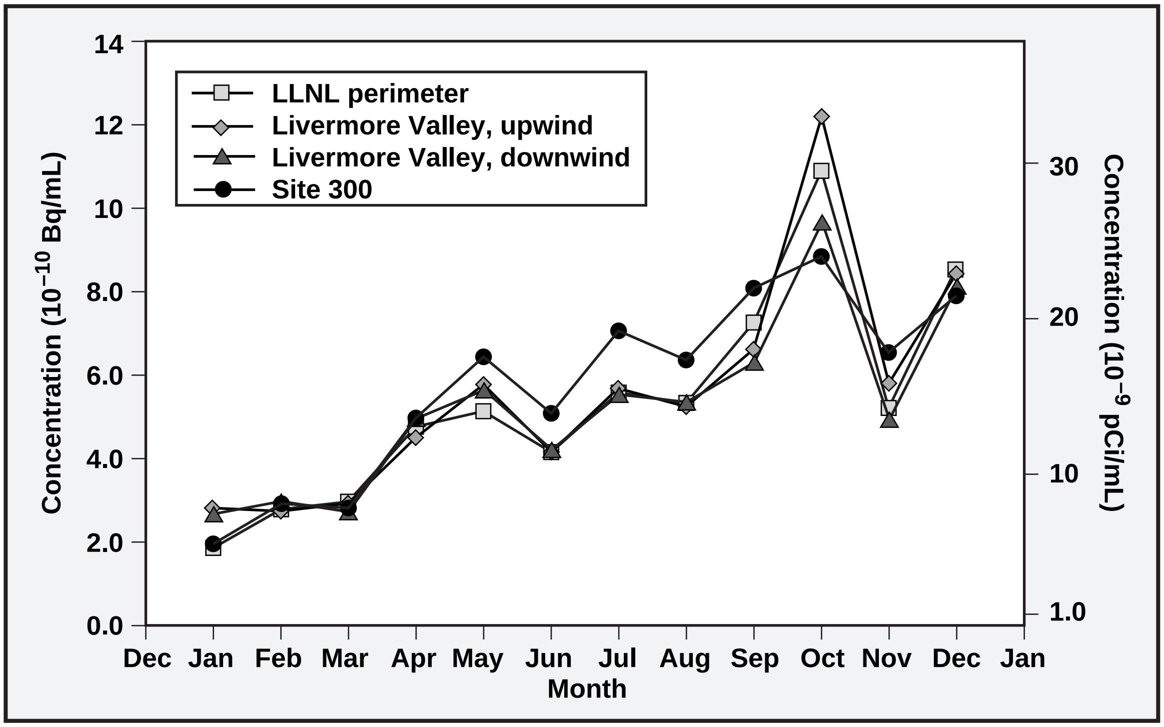

Figure 5-5. Monthly median gross beta concentrations in particulate air samples from the LLNL perimeter, Livermore Valley and Site 300 sampling locations, 1997.

Table 5-3. Gamma activity in air particulate samples, Livermore site perimeter and Site 300, 1997.

	^{7}Be	^{40}K	^{137}Cs	^{22}Na	^{226}Ra	^{228}Ra	^{228}Th
	(10^{-9} Bq/mL)	**(10^{-12} Bq/mL)**					
Livermore perimeter							
Median	3.4	23	<0.2	<0.3	<3.7	1.9	<1.1
Interquartile range	1.0	—[(a)]	—[(a)]	—[(a)]	—[(a)]	1.5	—[(a)]
Maximum	6.5	62	<0.3	0.7	<7.1	4.1	3.3
Median fraction of DCG[(b)]	2.2×10^{-6}	7.0×10^{-7}	$<1.2 \times 10^{-8}$	$<6.6 \times 10^{-9}$	$<1.0 \times 10^{-4}$	1.7×10^{-5}	$<7.1 \times 10^{-4}$
Site 300							
Median	4.2	23	<0.2	<0.3	<4.5	<1.2	<0.7
Interquartile range	0.9	—[(a)]	—[(a)]	—[(a)]	—[(a)]	—[(a)]	—[(a)]
Maximum	7.0	63	1.0	1.0	<9.0	2.5	3.0
Median fraction of DCG	2.8×10^{-6}	6.9×10^{-7}	$<1.4 \times 10^{-8}$	$<7.3 \times 10^{-9}$	$<1.2 \times 10^{-4}$	$<1.1 \times 10^{-5}$	$<4.8 \times 10^{-4}$
DCG (Bq/mL)	1.5×10^{-3}	3.3×10^{-5}	1.5×10^{-5}	3.7×10^{-5}	3.7×10^{-8}	1.1×10^{-7}	1.5×10^{-9}

a No measure of dispersion calculated. See Chapter 13, Quality Assurance.

b Derived Concentration Guide.

Table 5-4 shows the median, IQR, maximum, and median fraction of DCG for concentration of plutonium on glass fiber air filter samples collected in the Livermore Valley. (See Data Supplement, Table 5-4 for monthly data.) The highest off-site median concentration of ^{239}Pu occurred at the Livermore Water Reclamation Plant (LWRP). Soils near the LWRP contain some detectable plutonium, principally resulting from sludge-spreading operations following an estimated 1.2×10^{9} Bq (32 mCi) release to the sewer in 1967 (see Chapter 9, Soil and Sediment Monitoring). Resuspension of these soils probably accounts for the slightly higher median ^{239}Pu in air concentrations observed. However, the median observed value is <0.00001 of the DCG.

Table 5-4 also shows the concentrations of airborne ^{239}Pu on air filters from the LLNL perimeter locations. (See Data Supplement, Table 5-5 for the monthly data by location.) The highest concentration was registered at location SALV in October 1997; the concentration value is reported as 4.9×10^{-14} Bq / mL (1.3×10^{-24} Ci / mL), which represents 0.0001 of the DCG. The median concentration at location SALV is 7.7×10^{-15} Bq / mL (2.1×10^{-25} Ci / mL), which is lower than the previous year.

In June 1991, two air particulate sampling locations (B531 and CRED) were added as part of a special study to investigate the somewhat elevated levels of plutonium in air and surface soil in the southeast quadrant of the Livermore site (see Chapter 9, Soil and Sediment Monitoring, for general background on this study). These sampling locations are now part of our routine monitoring network and provide data for diffuse source dose assessments. **Table 5-4** shows the median concentrations of airborne ^{239}Pu at these two locations. (See Data Supplement, Table 5-6 for monthly data.) The median concentration of 4.7×10^{-14} Bq / mL (1.3×10^{-24} Ci / mL) at location B531 is higher than the median concentration for any of the other air particulate sampling locations, but is still only 0.0001 of the DCG. The higher concentrations have been attributed to historic operations, which included the operation of solar evaporators for plutonium-containing liquid waste (Silver et al. 1974).

Figure 5-6 shows the annual median concentrations of ^{239}Pu for locations SALV (on site) and FCC (off site) from 1982 to 1997. Location FCC represents a typical upwind background location, and SALV represents the perimeter location having the highest annual average for most of this 15-year period. The annual median concentration for FCC was -0.54×10^{-15} Bq / mL (-1.4×10^{-26} Ci / mL). **Figure 5-6** uses a log scale, therefore the positive value closest to the median is plotted. The higher values in the past at SALV may be attributed to historical activities at LLNL; improvements in operational processes in the immediate work area have contributed to the observed downward trend of the data.

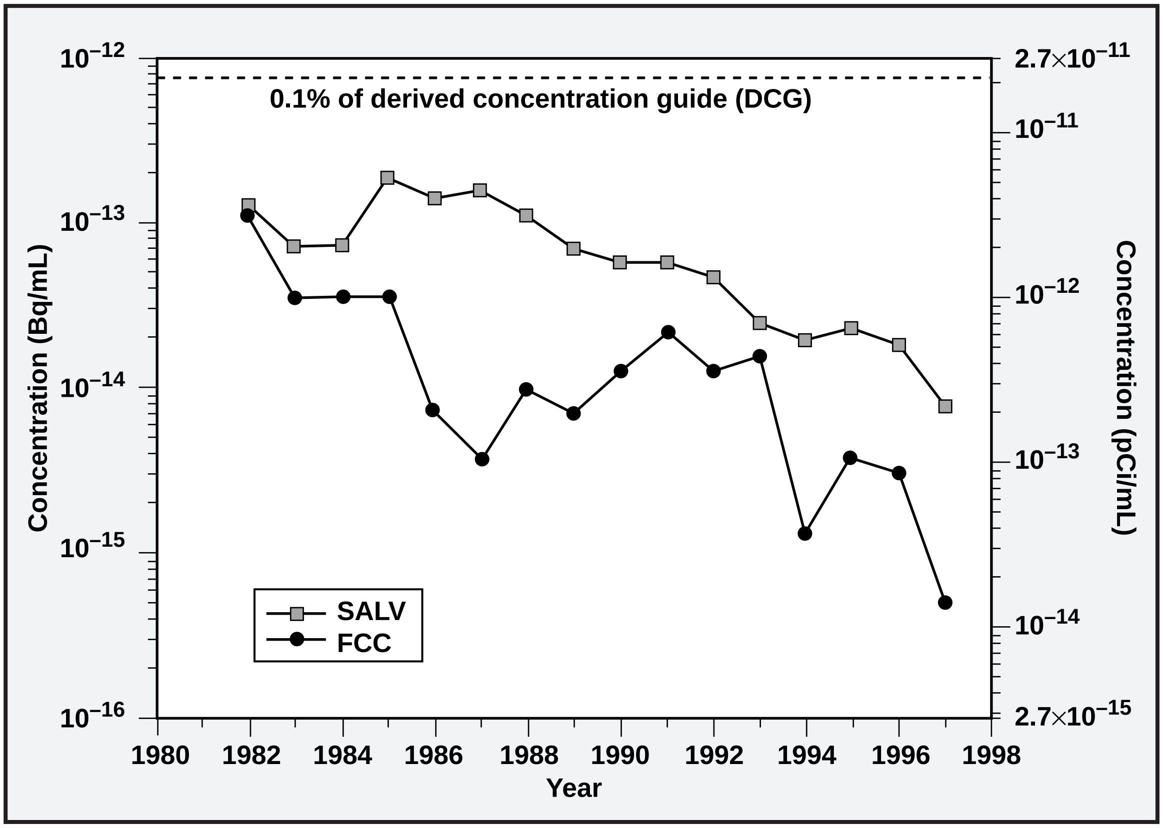

Figure 5-6. Median plutonium concentrations in air particulate samples at two locations, SALV and FCC, 1982 to 1997 (DCG = 7.4×10^{-10} Bq/mL).

The median ^{235}U and ^{238}U concentrations in air samples from the Livermore site perimeter are shown in **Table 5-5**. (See Data Supplement, Table 5-7 for monthly data.) The maximum measured concentration of ^{238}U (at location COW during October) is less than 0.0005 of the DCG. All $^{235}U/^{238}U$ median ratios are as expected for naturally occurring uranium; however, monthly data in the Data Supplement show some unexpected $^{235}U/^{238}U$ ratios, indicating other than natural uranium around the Livermore site perimeter. While no significant environmental impact stems from the observed ratios, their cause is not known but they have occurred sporadically in the past.

Typical gross alpha and gross beta activity from the low-volume sampling locations HOSP and FCC is 1.3×10^{-10} Bq/mL (3.5×10^{-21} Ci/mL) and 7.4×10^{-10} Bq/mL (2.0×10^{-20} Ci/mL), respectively. (See Data Supplement, Tables 5-8 and 5-9 for monthly median data.) These gross alpha values are higher than those reported from the high volume sampling systems. This is probably due to differences in the filter type. A study is being conducted to determine the cause.

Table 5-4. Plutonium activity in air particulate samples (in 10^{-15} Bq/mL), 1997.

Sampling location[a]	Median	Interquartile range	Maximum	Median fraction of DCG[b]
Livermore Valley downwind locations				
ALTA	2.4	5.4	4.7	3.2×10^{-6}
PATT	0.47	5.4	6.6	6.3×10^{-7}
TANK	–0.6	3.4	9.9	—[c]
ZON7	2.3	3.4	12	3.1×10^{-6}
Livermore Valley upwind locations				
FCC	–0.5	5.1	8.9	—[c]
FIRE	3.0	9.1	8.1	4.0×10^{-6}
HOSP	2.1	5.0	13	2.9×10^{-6}
RRCH	–2.8	3.6	7.4	—[c]
CHUR	4.6	6.7	15	6.2×10^{-6}
LLNL perimeter				
CAFE	6.5	5.6	18	8.8×10^{-6}
COW	3.0	8.4	11	4.0×10^{-6}
MESQ	8.8	7.0	17	1.2×10^{-5}
MET	6.7	5.3	12	9.1×10^{-6}
SALV	7.7	11	49	1.0×10^{-5}
VIS	6.2	5.3	15	8.4×10^{-6}
Special interest				
LWRP	11	8.8	24	1.4×10^{-5}
Diffuse sources				
B531	47	59	220	6.4×10^{-5}
CRED	4.5	6.6	29	6.0×10^{-6}
Site 300 on-site				
Site 300	3.6	2.2	17	4.8×10^{-6}
Site 300 downwind				
PRIM	–0.076	2.9	6.4	—[c]
TFIR	2.9	8.1	14	3.9×10^{-6}

a See **Figures 5-1, 5-2,** and **5-3** for sampling locations.

b Derived Concentration Guide = 7.4×10^{-10} Bq/mL (2×10^{-14} µCi/mL) for ^{239}Pu activity in air.

c Median fraction of DCG not calculated when median is a negative value.

Table 5-5. Uranium mass in air particulate samples, 1997.

Sampling location[a]	^{238}U[b] (10^{-5} µg/m^3)	^{235}U[c] (10^{-7} µg/m^3)	^{235}U/^{238}U[d] (10^{-3})
LLNL perimeter			
CAFE			
Median	4.85	3.27	6.89
Interquartile range	3.31	2.63	0.45
Maximum	13.2	9.56	NA[e]
Median fraction of DCG	1.6×10^{-4}	7.0×10^{-6}	NA
COW			
Median	5.29	3.71	7.10
Interquartile range	3.05	1.59	0.52
Maximum	16.1	11.6	NA
Median fraction of DCG	1.8×10^{-4}	7.9×10^{-6}	NA
MESQ			
Median	9.68	6.63	7.04
Interquartile range	8.74	6.30	0.63
Maximum	14.6	10.4	NA
Median fraction of DCG	3.2×10^{-4}	1.4×10^{-5}	NA
MET			
Median	2.96	2.21	7.06
Interquartile range	3.32	2.35	0.36
Maximum	8.77	6.21	NA
Median fraction of DCG	9.9×10^{-5}	4.7×10^{-6}	NA
SALV			
Median	3.64	2.42	6.61
Interquartile range	3.41	2.81	1.05
Maximum	11.9	8.54	NA
Median fraction of DCG	1.2×10^{-4}	5.2×10^{-6}	NA
VIS			
Median	3.18	2.11	7.07
Interquartile range	3.87	2.89	0.84
Maximum	9.40	6.80	NA
Median fraction of DCG	1.1×10^{-4}	4.5×10^{-6}	NA
Site 300 (composite)			
Median	4.65	3.41	7.05
Interquartile range	4.49	2.67	1.54
Maximum	18.2	12.8	NA
Median fraction of DCG	1.6×10^{-4}	7.2×10^{-6}	NA

a See **Figures 5-1** and **5-3** for sampling locations.

b Derived Concentration Guide = 0.3 µg/m^3 for ^{238}U activity in air.

c Derived Concentration Guide = 0.047 µg/m^3 for ^{235}U activity in air.

d Naturally occurring uranium has a ^{235}U/^{238}U ratio of 7.1×10^{-3}.

e NA = Not applicable.

Table 5-6 shows the median concentrations of tritiated water vapor for the Livermore Valley sampling locations. (See Data Supplement, Table 5-10 for biweekly data for each location.) The highest annual median concentration was observed at location ZON7. At approximately 5.9×10^{-8} Bq / mL (1.6×10^{-18} Ci / mL), this concentration represents 0.00002 of the DCG. The highest biweekly concentration was observed in October at ZON7. If it were a yearly average, this concentration, 4.9×10^{-7} Bq / mL (1.3×10^{-17} Ci / mL), would be 0.0001 of the DCG. The 1997 tritium values are generally similar to those reported last year.

Table 5-6. Tritium in air samples (in 10^{-9} Bq/mL), 1997.

Sampling location[(a)]	Detection frequency	Median	IQR[(b)]	Maximum	Median fraction of DCG[(c)]	Median dose (mSv)[(d)]
Livermore Valley						
ZON7	25/26	58.6	64.4	488	1.6×10^{-5}	1.3×10^{-6}
ALTA	6/8	<22.3	—[(e)]	44.8	$<6.0 \times 10^{-6}$	4.8×10^{-6}
XRDS	17/26	<12.9	—[(e)]	38.9	$<3.5 \times 10^{-6}$	2.8×10^{-6}
FIRE	15/26	<13.9	—[(e)]	28.2	$<3.8 \times 10^{-6}$	3.0×10^{-6}
VET	20/25	23.2	—[(e)]	76.2	6.3×10^{-6}	5.0×10^{-6}
HOSP	7/26	<10.5	—[(e)]	42.9	$<2.9 \times 10^{-6}$	2.3×10^{-6}
Livermore perimeter						
SALV	24/24	74.6	37.0	403	2.0×10^{-5}	1.6×10^{-5}
MESQ	22/26	34.4	50.9	102	9.3×10^{-6}	7.4×10^{-6}
CAFE	26/26	130	102	522	3.5×10^{-5}	2.8×10^{-5}
MET	21/25	24.8	—[(e)]	81.4	6.7×10^{-6}	5.3×10^{-6}
VIS	25/26	184	197	707	5.0×10^{-5}	3.9×10^{-5}
COW	26/26	119	88.7	364	3.2×10^{-5}	2.6×10^{-5}
POOL	24/24	267	192	1730	7.2×10^{-5}	5.7×10^{-5}
Diffuse on-site sources						
B292	26/26	112	97.5	796	3.0×10^{-5}	2.4×10^{-5}
B331	25/25	1360	796	9950	3.7×10^{-4}	2.9×10^{-4}
B514	26/26	4370	3780	7730	1.2×10^{-3}	9.4×10^{-5}
B624	26/26	4180	2660	7730	1.1×10^{-3}	9.0×10^{-4}
Site 300 off site						
PRIM	5/24	<7.71	—[(e)]	10.1	$<2.1 \times 10^{-6}$	1.7×10^{-6}

a See **Figures 5-1**, **5-2**, and **5-3** for sample locations.

b Interquartile range.

c Derived Concentration Guide = 3.7×10^{-3} Bq/mL (1×10^{-7} µCi/mL).

d 1 mSv = 100 mrem.

e Interquartile range not calculated. See Chapter 13, Quality Assurance.

Table 5-6 also shows the median concentrations of tritiated water vapor that were observed at the Livermore site perimeter sampling locations. (See Data Supplement, Table 5-11 for biweekly data.) The highest annual median concentration was observed at location POOL, which was 2.7×10^{-7} Bq / mL (7.3×10^{-18} Ci / mL), or 0.00007 of the DCG.

Diffuse sources of tritium on the Livermore site are monitored at air tritium sampling locations B331, B292, B514, and B624. **Table 5-6** shows the median concentrations of tritiated water vapor for these sampling locations. (See Data Supplement, Table 5-12 for biweekly data.) The highest median concentration was observed at location B514. This concentration was 4.4×10^{-6} Bq / mL (1.2×10^{-16} Ci / mL) and represents 0.001 of the DCG. The highest biweekly tritium concentration, 1.0×10^{-5} Bq / mL (2.7×10^{-16} Ci / mL), was observed in November at location B331. If it were a yearly average, this concentration would represent 0.003 of the DCG.

The B331 location is near the Tritium Facility (Building 331), in which LLNL personnel have reduced operations in recent years and performed significant inventory reduction and cleanup activities. During this process, tritium-contaminated equipment slated for disposal is stored in a waste accumulation area before being sent to Hazardous Waste Management facilities. During 1997, outgassing from such waste processing released an estimated 9.2×10^{10} Bq (2.5 Ci) of tritium to the atmosphere outside of Building 331.

The B624 location is situated in the Building 612 yard, which is dedicated to hazardous waste, radioactive waste, and mixed-waste management activities. The yard consists of several areas where waste containers that are outgassing tritium are stored outdoors.

The B514 sampling location is in a hazardous waste management area where tritium-contaminated waste is treated, and the B292 location is near an underground retention tank that had previously leaked. The concentrations in air at the B514 sampling location are variable because of the changing concentrations of tritium in the waste stream. The 1996 median concentrations at B292 are similar to the median concentrations in 1996.

Beryllium in Air

The median concentrations of airborne beryllium for the Livermore site perimeter sampling locations are shown in **Table 5-7**. (See Data Supplement, Table 5-13 for monthly data.) The highest value of 25.8 pg / m^3 was found in the August composite at location MESQ and was most likely the result of ground moving activities west of LLNL. The median concentration for this location is 0.001 of the monthly ambient concentration guide (ACG) of 10,000 pg / m^3 established by the Bay Area Air Quality Management District (BAAQMD) and the Environmental Protection Agency (EPA).

Table 5-7. Beryllium in air particulate samples (in pg/m^3), Livermore site perimeter and Site 300, 1997.

Sampling location[(a)]	Detection frequency	Median	Interquartile range	Maximum
Livermore perimeter				
SALV	12/12	5.5	4.8	22
MESQ	12/12	15	16	26
CAFE	12/12	7.9	6.0	14
MET	12/12	6.1	6.3	14
VIS	12/12	5.3	4.4	13
COW	12/12	8.6	7.1	18
Site 300				
EOBS	11/12	3.4	4.8	10
GOLF	12/12	5.3	7.4	14
TFIR	12/12	11	11	20
801E	12/12	10	9.5	17

[a] See **Figures 5-1** and **5-3** for sampling locations. Summary results for sampling locations that were removed in April are not reported. Monthly data are reported in Data Supplement, Tables 5-13 and 5-19.

Figure 5-7 is a plot of the median beryllium concentration at the Livermore site perimeter from 1974 through 1997. The overall median concentration during this time period was calculated to be 0.002 of the ACG. Unless there is a change in LLNL's operations, it is expected that the beryllium levels will remain unchanged.

Site 300

Airborne Radioactivity

Most gross alpha determinations at Site 300 were at or near the analytical limit of detection for the method. **Table 5-2** shows the monthly gross alpha and gross beta median, IQR, and maximum for sampling locations at Site 300. (See Data Supplement, Table 5-14 for monthly data.) The monthly median gross alpha and gross beta concentrations are shown in **Figures 5-4** and **5-5**. The Site 300 gross beta results show a similar pattern to those found at the Livermore site. Typical gross alpha activity is 1.5×10^{-11} Bq / mL (4.0×10^{-22} Ci / mL).

Typical gross beta activity is 5.5×10^{-10} Bq / mL (1.5×10^{-20} Ci / mL). The primary sources of observed gross alpha and gross beta activity are naturally occurring radioisotopes of uranium and thorium and their decay products, and any residual fallout from atmospheric weapons testing and the Chernobyl reactor accident (1986).

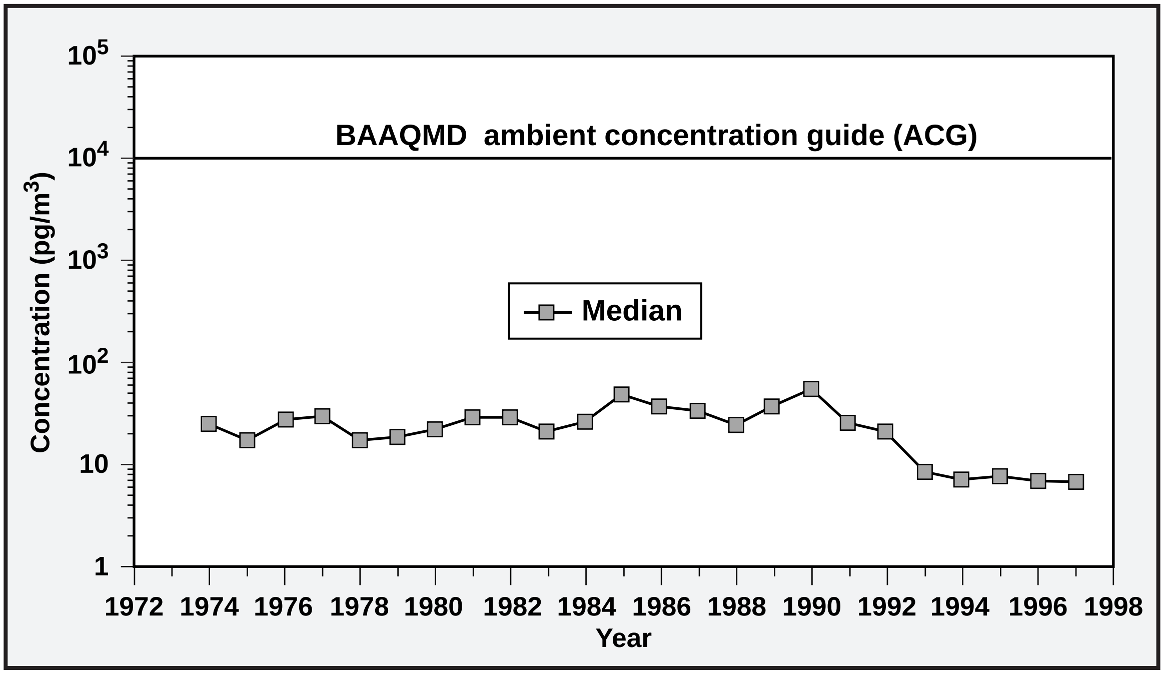

Figure 5-7. Median concentration of beryllium in air particulate samples taken at the Livermore site perimeter, 1974 to 1997.

Table 5-3 lists the annual median activities, IQR, maximum, the fraction of the DCG, as well as the DCG, of gamma-emitting radionuclides in samples from Site 300. (See Data Supplement, Table 5-15 for monthly data.) All these radionuclides were measured at concentrations significantly below the DCGs. Of the nuclides tabulated, ^{7}Be, ^{40}K, ^{226}Ra, ^{228}Ra, and ^{228}Th are naturally occurring. The primary source of ^{137}Cs normally is long-term global fallout and resuspension.

Table 5-4 shows the median concentration of ^{239}Pu on air-filter samples collected from Site 300. (See Data Supplement, Table 5-16 for monthly data.) The highest concentration of ^{239}Pu was observed in the August composite at a level of 1.7×10^{-14} Bq / mL (4.6×10^{-25} Ci / mL), or 0.00002 of the DCG.

Table 5-5 shows the median concentration of ^{238}U, ^{235}U, and the ^{235}U / ^{238}U ratio on air samples from Site 300. (See Data Supplement, Table 5-17 for monthly data.) The highest concentration of ^{238}U was observed in the October composite at a level of 1.8×10^{-4} µg / m^3 (0.0006 of the DCG). The highest concentration of ^{235}U was also observed in the October composite at a level of 1.3×10^{-6} µg / m^3 (0.00003 of the DCG). The overall levels were essentially the same as those reported in previous years.

The ratio of ^{235}U to ^{238}U can be used to identify the source of the uranium. Both ^{235}U and ^{238}U occur naturally in the area, but only 0.7% of the naturally occurring uranium is ^{235}U, and the remainder is almost entirely ^{238}U. Because Site 300 operations use depleted uranium that contains very little ^{235}U, it follows that if the ratio remains constant and near 0.7% (within the limit of sampling and analytical error), then the ^{238}U measured is from natural sources. The $^{235}U/^{238}U$ ratios in January, February, and June are less than expected for natural sources, which indicate some impact from operations at Site 300. The median concentration of ^{238}U for 1997, however, is only 0.0001 of the DCG (DOE Order 5400.5).

Table 5-6 shows the median concentration of tritiated water vapor that was observed at the new sampling location (PRIM) near Site 300. (See Data Supplement, Table 5-18 for biweekly data.) The annual median concentration is $<7.7 \times 10^{-9}$ Bq/mL (2.1×10^{-19} Ci/mL), or 0.000002 of the DCG.

Beryllium in Air

The detection frequency, median, IQR, and maximum concentrations of airborne beryllium for the Site 300 sampling locations are shown in **Table 5-7**. (See Data Supplement, Table 5-19 for monthly data.) The highest beryllium concentration of 19.7 pg/m^3 occurred in September at location TFIR. The median concentration for this location is 0.001 of the federal and state ambient concentration limit, which is 10,000 pg/m^3.

Environmental Impact

The environmental impacts from both radioactive and nonradioactive effluents are described in this section.

Radioactive Materials

LLNL operations involving radioactive materials had little impact on radionuclide concentration in ambient air in 1997. Radionuclide concentrations in air at the Livermore site and in the Livermore Valley are well below levels that would cause concern to the environment or public health according to existing regulatory standards.

The diffuse tritium sources at B292, B331, B514, and B624 have a localized effect; the tritium concentrations in October at all the site perimeter and off-site locations were elevated.

The concentrations of radionuclides measured around Site 300 and in the city of Tracy were well below all standards and, except for uranium isotopes, reflect background or naturally occurring levels of these chemicals. (See Chapter 12, Radiological Dose Assessment, for discussion of estimated dose from these data.) The $^{235}U/^{238}U$ ratios in January, February, and June are less than the ratio of naturally occurring concentrations of these isotopes, which suggests the presence of depleted uranium in Site 300 air samples. This depleted uranium can result from current testing of explosives or resuspension of material left over from testing in previous years.

Nonradioactive Materials

The concentrations of beryllium at both sites can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and the air of the Livermore area and Central Valley typically contains 10 to 100 $\mu g/m^3$ of particulates. Using a value of 50 $\mu g/m^3$ for an average dust load and 1 ppm for beryllium content of dust, a conservative airborne beryllium concentration of 50 pg/m^3 can be predicted. The overall annual medians for the Livermore site and Site 300 are 6.6 pg/m^3 and 3.8 pg/m^3, respectively. These data are lower than predicted, well below standards, and do not indicate the presence of a threat to the environment or public health.

6

Sewerable Water

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Introduction

In 1997, the Livermore site discharged approximately 0.91 million liters (ML) per day of wastewater to the City of Livermore sewer system, an amount that constitutes 4.4% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories / California (SNL / California), which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system (**Figure 6-1**). In 1997, SNL / California generated approximately 20% of the total effluent discharged from the Livermore site. LLNL's wastewater contains sanitary sewage and industrial wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below in the Pretreatment and Categorical Discharges section.

The effluent is treated at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management Program, the treated sanitary wastewater is transported out of the valley through a pipeline and discharged into San Francisco Bay. A small portion of this treated wastewater is used for summer irrigation of the adjacent municipal golf course. Sludge from the treatment process is disposed of in sanitary landfills.

LLNL receives water from two suppliers. LLNL's primary water source is the Hetch-Hetchy Aqueduct. Secondary or emergency water deliveries are taken from the Alameda County Flood Control and Water Conservation District Zone 7. This water is a mixture of ground water and water from the South Bay Aqueduct of the State Water Project. Water quality parameters for the two sources are obtained from the suppliers and are used to evaluate compliance with the discharge permit conditions that limit changes in water quality between receipt and discharge.

Preventive Measures

Administrative and engineering controls at the Livermore site are designed to prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Waste generators receive training on proper waste handling. LLNL personnel review facility procedures and inspect processes for inappropriate discharges. Retention tanks collect wastewater from processes that might release contaminants in quantities sufficient to disrupt operations at the LWRP. Ground water generated from remediation treatment, hydraulic tests, and volatile organic compound (VOC) treatability studies is analyzed for pollutants of concern and must meet permitted criteria or LWRP approval must be obtained before it can be discharged to the sanitary sewer. Finally, to verify the success of training and control equipment, wastewater is sampled and analyzed not only at the significant points of generation, as defined by type and quantity of contaminant generated, but also at the point of discharge to the municipal sewer system.

For facilities with installed retention tank systems, collected wastewater is discharged to the sanitary sewer only if analytical laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). LLNL developed internal discharge guidelines for specific sources and operations to ensure that sewer effluent for the entire site complies with LLNL's waste discharge permit. If pollutant levels exceed permissible concentrations, the wastewater is treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or it is shipped to an off-site treatment or disposal facility. Liquids containing radioactivity are handled on site and may be treated using processes that reduce the activity to levels well below those required by DOE Order 5400.5. Internal guidelines for retention tank systems and specific sources and operations are discussed below in the "Pretreatment and Categorical Discharges" section.

For the year as a whole, the monitoring data reflect the success of LLNL's discharge control program in preventing any significant impact on the operations of Livermore's treatment plant and are generally consistent with past values.

Continuous Monitoring

LLNL's sanitary sewer discharge permit requires continuous monitoring of the effluent flow rate and pH. Samplers collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, toxic chemicals, and water-quality parameters. In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might upset the LWRP treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for pH, selected metals, and radioactivity. If concentrations above warning levels are detected, an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control and automatically notifies the LWRP in the event that contaminants are detected. Trained staff respond to all alarms to evaluate the cause and take appropriate action.

Diversion System

LLNL operates and maintains a diversion system that is automatically activated when the continuous monitoring system sounds an alarm. The diversion system ensures that all but the first few minutes of the affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any required cleanup. Up to 775,000 L of potentially contaminated sewage can be held pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if it meets LLNL's wastewater discharge permit limits), shipped for off-site disposal, or treated at LLNL's Hazardous Waste Management Facility. The majority of all diverted sewage in 1997 was returned to the sanitary sewer.

Satellite Monitoring

In 1991, LLNL completed the implementation of a network of 10 satellite monitoring stations that operated in conjunction with the sewer monitoring station (**Figure 6-1**). The satellite monitoring stations were positioned at strategic locations within the main sewer system to help pinpoint the on-site area from which a release might have originated. Each station consisted of an automatic sampler that collected samples on a time-proportional basis. If there was a release, these samples were analyzed. In October 1997, this satellite monitoring station network was decommissioned. In addition to ergonomic issues associated with the routine maintenance of the sampling equipment, the network did not prove to be sufficiently helpful in identifying an on-site area as the source of a release. An alternative to the network will be installed in 1998. This alternative will mitigate the most frequent type of inadvertent discharges (low pH) observed in 1996 and 1997 (see Chapter 2, **Table 2-10**).

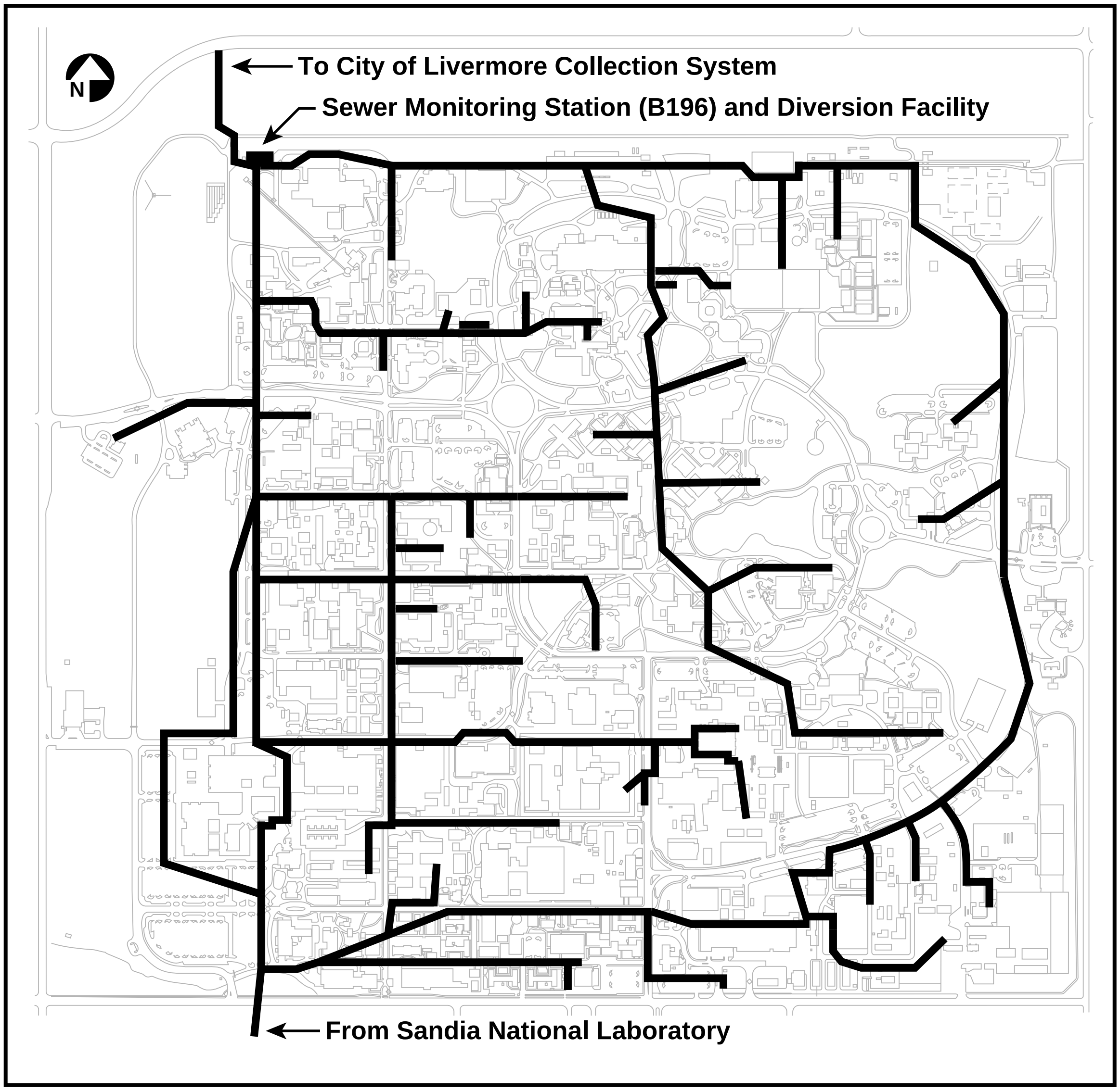

Figure 6-1. Sanitary sewer system including trunk laterals and monitoring station.

Pretreatment and Categorical Discharges

The General Pretreatment Regulations establish both general and specific standards for the discharge of prohibited substances (40 CFR 403.5) that apply to all industrial users. Self-monitored pretreatment programs are required at both the Livermore site and Site 300 by the LWRP under the authority of San Francisco Bay Regional Water Quality Control Board. The sampling and monitoring of nondomestic, industrial sources covered by pretreatment standards defined in 40 CFR 403 is required in the 1997–1998 Wastewater Discharge Permit (No. 1250) issued for the discharge of wastewater from

LLNL into the City of Livermore sewer system. Permit 1250 discharge limits are listed in **Table 6-1**. These limits are applied at the site boundary before wastewater enters the municipal collection system (see **Figure 6-1**).

Table 6-1. Limits under permit 1250 for discharges into the municipal sewer.

Constituent	Discharge limit
Metals (mg/L)	
Arsenic	0.06
Cadmium	0.14
Copper	1.0
Chromium (total)	0.62
Lead	0.20
Mercury	0.01
Nickel	0.61
Silver	0.20
Zinc	3.0
Cyanide (mg/L)	0.04
Toxic organics (total)	1.0
pH (pH units)	5–10

Categorical Standards are published by the Environmental Protection Agency (EPA) as separate regulations and contain numerical limits for the discharge of pollutants from specified processes (or industrial categories). The LWRP has identified specific LLNL wastewater generating processes that fall under the definition of two Categorical Standards: electrical and electronic components (40 CFR 469), and metal finishing (40 CFR 433). The discharge limits for these standards are shown in **Table 6-2**.

During 1997, LLNL maintained compliance with categorical standard discharge limits for significant industrial processes that discharge to the sanitary sewer by reviewing retention-tank data prior to discharge and applying the appropriate categorical discharge limits. This monitoring data is reported to the LWRP in semiannual reports.

In December 1996, LLNL was notified of EPA's decision regarding the request for exemption from the Categorical Standards in a report of their 1995 Clean Water Act (CWA)/ NPDES inspection of LLNL's Livermore site. The EPA report stated that although they do exempt research laboratories from regulation under the categorical standards, they do not exempt operations in support of research, such as parts fabrication or waste handling. Therefore, LLNL resumed self-monitoring of its federally regulated discharges in 1997 as prescribed in the Wastewater Discharge Permit (No. 1250).

Tables 6-2 and **6-3** show LLNL's internal discharge limits for wastewaters discharged to the sanitary sewer. Those processes that discharge to the sanitary sewer are subject to the pretreatment self-monitoring program specified in the Wastewater Discharge Permit issued by the LWRP. In 1997, 13 exceptions to the pollutant limitations of the discharge permit were observed and are discussed below in the "Environmental Impact of Nonradioactive Liquid Effluents" section.

Table 6-2. Discharge limits for nonradioactive pollutants in wastewaters at point of discharge into LLNL sewer.

Parameter	Discharge limits			
	Internal[a]	Metal finishing[b]	Electric components[b]	Permit 1510G
Metals (mg/L)				
Arsenic	NA[c]	NA	0.83	0.06
Cadmium	0.9	0.26	—[d]	0.14
Chromium (total)	4.9	1.71	—[d]	0.62
Copper	10	2.07	—[d]	1.00
Lead	4.9	0.43	—[d]	0.20
Mercury	0.05	—[d]	—[d]	0.01
Nickel	5	2.38	—[d]	0.61
Silver	1	0.24	—[d]	0.20
Zinc	15	1.48	—[d]	3.00
Organics (mg/L)				
TTO[e]	4.57	2.13	1.37	1.00
BTEX[f]	NA	NA	NA	NA
Other (mg/L)				
Cyanide[g]	5	0.65	—[d]	0.04
pH (pH units)	5-10	5-10	5-10	5-10

Note: Permit 1510G is discussed in the following section, Discharges of Treated Ground Water.

a These standards were established to meet the City of Livermore's requirements at the point of discharge to the Municipal Sewer (Building 196).

b These standards were specified by EPA. By regulation, the EPA or City of Livermore limit is used, whichever is lower. Internal limits apply where no standard is specified.

c NA = Not applicable.

d Noncategorical limits apply.

e Total toxic organics, as defined by the Livermore Municipal Code.

f Benzene, toluene, ethyl benzene, and xylene.

g Limits apply to cyanide discharges other than cyanide salts. CN salts are classified by the State of California as "extremely hazardous waste" and cannot be discharged to the sewer.

Table 6-3. LLNL's internal discharge limits for radioisotopes in wastewaters. There is no gross gamma limit; isotope-specific limits apply.

Parameter	Individual discharges	Total daily limit for site
Gross alpha	11.1 Bq/L (0.3 nCi/L)	185 kBq (5.0 µCi)
Gross beta	111 Bq/L (3.0 nCi/L)	1.85 MBq (50.0 µCi)
Tritium	185 kBq/L (5.0 nCi/L)	3.7 GBq (100.0 mCi)

Discharges of Treated Ground Water

LLNL's ground water discharge permit (1510G, 1997) allows ground water from hydraulic tests and VOC treatability studies to be discharged to the City of Livermore sanitary sewer in compliance with **Table 6-2** effluent limitations taken from the Livermore Municipal Code. Through negotiation with the LWRP, in 1997 the conditions of the two permits (1508G and 1510G) previously issued for discharge of treated ground water to the sanitary sewer were combined to create a single permit, 1510G.

During 1997, over 5.7 ML of ground water from sitewide CERCLA cleanup activities was discharged to the sanitary sewer. Discharges were primarily from start-up operations associated with portable treatment unit construction and testing. Twelve separate discharges were sampled and discharged to the sewer during this period, all in compliance with the total toxic organic (TTO) self-monitoring permit provisions of self-monitoring permit 1510G. Concentrations of regulated compounds were all below discharge limits. Complete monitoring data are presented in the Data Supplement, Chapter 6.

Radioactive Pollutants in Sewage

Monitoring Results

Determination of the total radioactivity released from tritium, alpha emitters, and beta emitters is based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever is higher (see **Table 6-4**). The 1997 combined releases of tritium and alpha and beta sources were 9.4 GBq (0.25 Ci). The total is based on the results shown in **Table 6-4**; unlike the years prior to 1996, the total does not include a contribution from Sandia National Laboratories (SNL)/California, which concluded all of its tritium research activities as of October 1994. The cleanup activities at their former tritium research laboratories were completed by October 1995. The annual mean concentration of tritium in LLNL sanitary sewer effluent was 0.027 Bq/mL (0.73 pCi/mL).

Table 6-4. Estimated total radioactivity in LLNL sanitary sewer effluent, 1997.

Radioactive emitter	Estimate based on effluent activity (GBq)[a]	Limit of sensitivity (GBq)
Tritium	9.1	3.7
Alpha sources	0.062	0.060
Beta sources	0.23	0.052

a 37 Gbq = 3.7×10^{10} Bq = 1 Ci.

The concentrations of ^{239}Pu, ^{137}Cs, and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 6-5**. The tritium numbers are based on the flow-weighted average of the individual daily sample results for a given month. The plutonium and cesium numbers are the direct result of analysis of monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. At the bottom of the table, the total activity released is given by radioisotope. This was calculated by multiplying each sample result by the total flow volume over which the sample was collected, and summing up over all samples. The total activity released for each radioisotope is a conservative value; the limit of sensitivity was used in the calculation when the limit of sensitivity was greater than the actual activity reported. Also included in the table are fractions of DOE and 10 CFR 20 limits, discussed in the Environmental Impact section of this chapter.

The historical trend in the monthly average concentration of tritium is shown in **Figure 6-2**. Also included in the figure is the DOE tritium limit (370 Bq/mL), discussed in the Environmental Impact section of this chapter. The trend indicates a well-controlled tritium discharge, orders of magnitude below the DOE tritium limit.

Figure 6-3 shows the average monthly plutonium and cesium concentrations in sewage since 1988. The annual mean concentration of ^{137}Cs was 4.5 µBq/mL (1.2×10^{-4} pCi/mL); the annual mean ^{239}Pu concentration was 0.63 µBq/mL (1.7×10^{-5} pCi/mL).

Environmental Impact

During 1997, no inadvertent releases exceeded any discharge limits for release of radioactive materials to the sanitary sewer system.

Table 6-5. Various radionuclides in sanitary sewer effluents, LLNL and Livermore Water Reclamation Plant (LWRP), 1997.

Month	^{3}H (mBq/mL)[(a)]		^{137}Cs (μBq/mL)[(a)]		^{239}Pu (nBq/mL)[(a)]		^{239}Pu (mBq/dry g)[(a)]
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge[(b)]
Jan	13 ± 5	–3.0	2.1 ± 0.4	<0.38	287 ± 62	–18.0 ± 23.9	
Feb	77 ± 7	–3.2	36 ± 2	1.17 ± 0.04	4370 ± 592	17.3 ± 38.5	
Mar	88 ± 6	4.1	10 ± 1	0.29 ± 0.23	1370 ± 144	–0.73 ± 9.40	1.2 ± 0.1
Apr	17 ± 6	2.3	0.92 ± 0.57	<0.62	159 ± 54	1.9 ± 13.3	
May	8.8	2.6	0.57	<0.73	169 ± 76	31.5 ± 40.0	
Jun	7.6	3.1	1.7 ± 0.4	<0.52	171 ± 54	1.8 ± 11.3	2.0 ± 0.2
Jul	8.9	–2.0	1.2 ± 0.4	<0.73	224 ± 55	–2.19 ± 8.18	
Aug	4.1	–3.4	1.1 ± 0.3	<0.40	147 ± 37	–1.78 ± 4.48	
Sep	28 ± 7	0.85	1.7 ± 0.6	<0.50	219 ± 53	1.79 ± 7.59	0.68 ± 0.11
Oct	3.5	1.4	1.4 ± 0.5	<0.47	389 ± 90	–11.8 ± 15.6	
Nov	2.5	–2.3	1.2 ± 0.9	<0.53	335 ± 66	–5.44 ± 5.99	
Dec	3.9	0.012	1.5 ± 0.7	<0.68	437 ± 84	3.31 ± 9.92	0.36 ± 0.07
Median	**9**	**0.4**	**1.4**	**0.53**	**256**	**–1.3**	**0.94**
IQR[(c)]	**16**	**4.8**	**0.6**	**—[(d)]**	**230**	**7.3**	**0.81**
	pCi/mL[(e)]						**pCi/ dry g[(e)]**
Median	**0.24**	**0.01**	**3.8×10^{-5}**	**$<1.4 \times 10^{-5}$**	**6.9×10^{-6}**	**-3.4×10^{-8}**	**0.025**
IQR[(c)]	**0.42**	**0.13**	**1.6×10^{-5}**	**—[(d)]**	**6.2×10^{-6}**	**2.0×10^{-7}**	**0.022**
	Annual total discharges by radioisotope						
	^{3}H		**^{137}Cs**		**^{239}Pu**		**Total[(f)]**
Bq/y	**9.1×10^{9}**		**1.5×10^{6}**		**2.1×10^{5}**		**9.1×10^{9}**
Ci/y	**0.25**		**4.1×10^{-5}**		**5.7×10^{-6}**		**0.25**
	Fraction of limit[(g)]						
DOE	**7.4×10^{-5}**		**8.1×10^{-6}**		**1.7×10^{-6}**		**7.4×10^{-5}**
10 CFR 20	**0.049**		**1.2×10^{-5}**		**8.5×10^{-5}**		**—[(h)]**

Note: Radionuclide results are reported ±2σ; see Chapter 13, Quality Assurance.

a Ranges are only listed for activities that are above the limit of sensitivity.

b Sludge from LWRP digesters is dried before analysis. The resulting data indicate the plutonium concentration of the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

c Interquartile range.

d Because of the large number of nondetections, the interquartile range is omitted. See Chapter 13, Quality Assurance.

e 1 Ci = 3.7×10^{10} Bq.

f Does not include gross alpha and beta results shown in **Table 6-4**.

g Fraction of limit calculations are based on the annual total discharge for a given isotope and the corresponding monthly concentration-based limit (multiplied by the annual volume of Livermore site effluent) or, preferably the annual limit, if one exists.

h The fraction of the 10 CFR 20 limit is not presented because tritium discharges have an annual limit and cesium and plutonium discharges have monthly concentration-based limits. See the individual fractions for each of these radioisotopes.

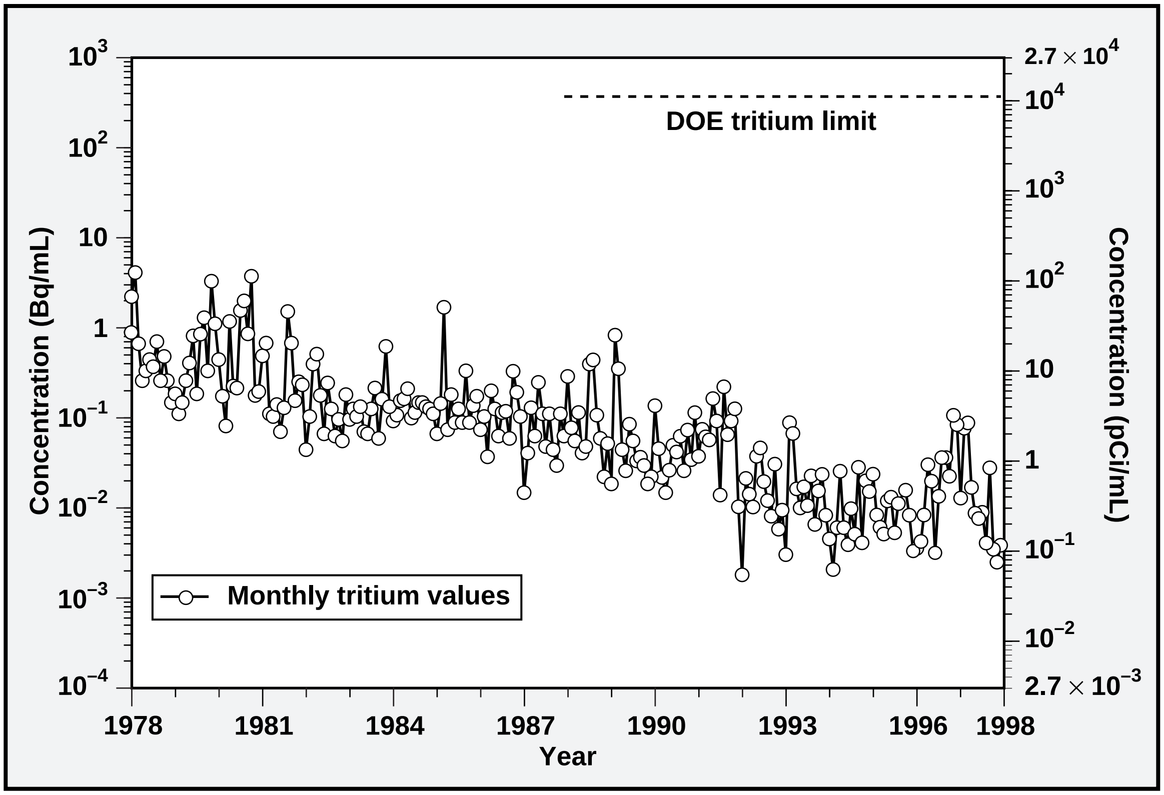

Figure 6-2. Historical trend in tritium concentration in LLNL sewage.

DOE Order 5400.5 established DOE policy requiring that radiological releases to the sanitary sewer comply with legally applicable local and state regulations and that LLNL implement standards generally consistent with those of the Nuclear Regulatory Commission. The most stringent of these limits was adopted in Title 17 of the California Code of Regulations. As a federal facility, LLNL is formally exempt from the requirements of state regulations but follows those requirements under the guidance of DOE. Title 17 contained a limit on discharges of radioactivity in sewage of 37 GBq (1 Ci) each year; it also listed limits on the daily, monthly, and annual concentration for each specific radionuclide.

In 1994, the discharge requirements previously found in Title 17 were removed and the requirements in Title 10 of the Code of Federal Regulations, Part 20, incorporated by reference. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci); in addition, it specifies that the discharge material must be soluble and lists limits on monthly concentrations.

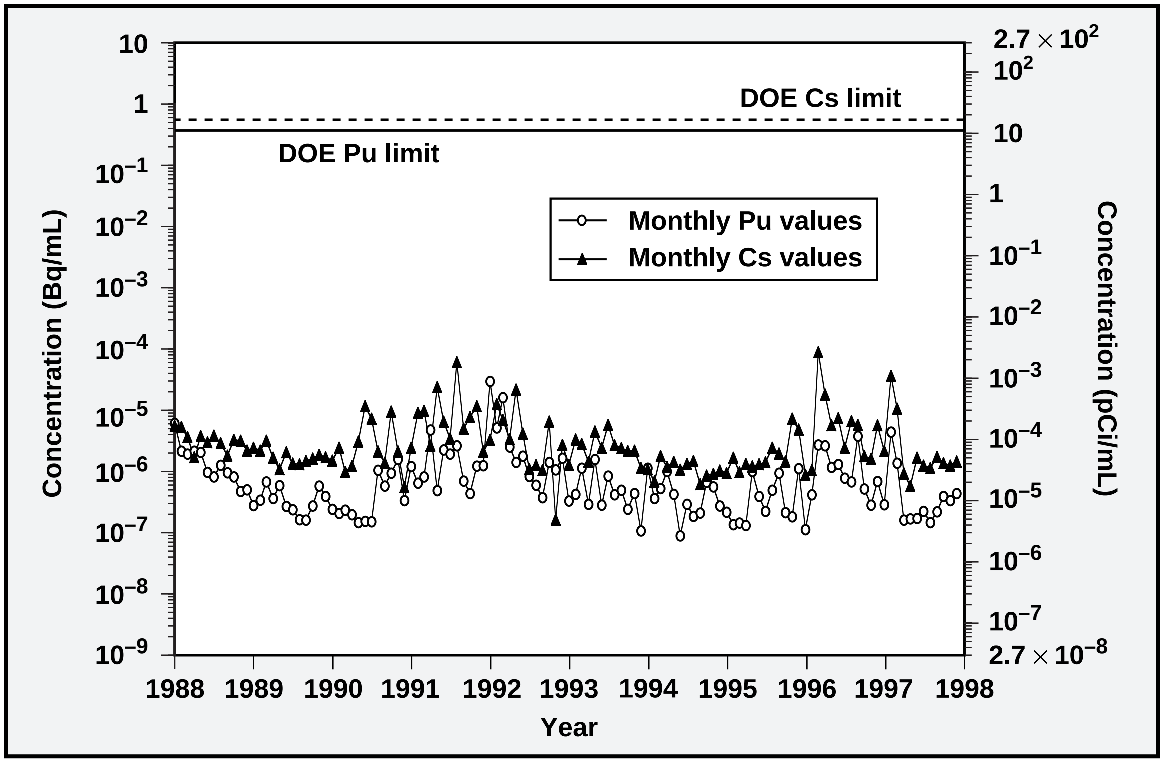

Figure 6-3. Historical trends in plutonium and cesium concentration in LLNL sewage.

Table 6-6 summarizes the discharge requirements of Title 10. Because Title 10 permits and therefore applies to only soluble discharges, and because the plutonium in LLNL effluent is in both the soluble and insoluble forms, LLNL follows the discharge requirements for ^{239}Pu in DOE Order 5400.5. This assumption is supported by our experience during the sewer system evaluation, when increased cleaning led to higher plutonium concentrations in LLNL sewage (Gallegos et al. 1992). This indicates that a portion of the plutonium discharges from LLNL facilities is deposited on the sewer pipes, and when these deposits are liberated and discharged from the LLNL site, they are, by their nature, insoluble.

Table 6-6 also includes the total activity that could have been discharged by LLNL during a given period (monthly and annually) using 10 CFR 20 monthly concentrations in conjunction with the annual caps and assuming the 1997 average monthly flow rate and total flow volume. As the table shows, the Title 10 concentration limits for tritium for facilities such as LLNL that generate wastewater in large volumes are overridden by the limit on total tritium activity (185 GBq) dischargeable

Table 6-6. Sewer discharge release limits for ^{3}H, ^{137}Cs, and ^{239}Pu.

	^{3}H	^{137}Cs	^{239}Pu
10 CFR 20 concentrations used to establish release limits (Bq/mL)	370	0.37	0.0074
10 CFR 20 (GBq)			
Monthly	185[a]	10	0.21
Yearly	185[a]	37[b]	2.5
DOE annualized discharge limit for application of BAT[c] (Bq/mL)	370	0.56	0.37

a 10 CFR 20 imposes a 185-GBq (5-Ci) limit for the tritium radiation released.

b 10 CFR 20 imposes a 37-GBq (1-Ci) combined limit on the total of all radiation released (excluding tritium and C^{14}, which have separate 10 CFR 20 limits of 185 GBq and 37 GBq, respectively); i.e., the total release of all isotopes must not exceed 37 GBq. If a total of 37 GBq of a particular isotope were released during the year, this would require that no other isotopes be released.

c The DOE annualized discharge limit for application of best available technology (BAT) is five times the Derived Concentration Guide (DCG; ingested water) for each radionuclide released.

during a single year. In 1997, the total LLNL tritium release was 4.9% of the corresponding Title 10 limit. Total LLNL releases (**Table 6-4**), in the form of alpha and beta emitters (excluding tritium), were 0.79% of the corresponding Title 10 limit.

DOE has also established criteria for the application of best available technology to protect public health adequately and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each specific radionuclide discharged to publicly owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeded its concentration limit, LLNL would be required to improve discharge control measures until concentrations were again below the DOE limits. **Table 6-6** presents the DCGs for the specific radioisotopes of most interest at LLNL.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 7.4×10^{-5} (that is, 0.0074%) of the DOE DCG (and the Title 10 limit); the annual average concentration of ^{137}Cs was 8.1×10^{-6} (0.00081%) of the DOE DCG (and 1.2×10^{-5} or 0.0012% of the Title 10 limit); and the annual average ^{239}Pu concentration was 1.7×10^{-6} (0.00017%) of the insoluble ^{239}Pu DOE DCG, 1.2×10^{-4} (0.012%) of the soluble ^{239}Pu DOE DCG, and 8.5×10^{-4} (0.085%) of the Title 10 limit. The combined discharges were therefore 8.4×10^{-5} (0.0084%) and 2.0×10^{-4} (0.020%) of the DCG, assuming exclusively insoluble and soluble ^{239}Pu contributions, respectively. As discussed earlier in this section, the plutonium in LLNL effluent is assumed to be present both in the soluble and insoluble forms.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 6-7** summarizes the radioactivity in liquid effluent released over the past 10 years. During 1997, a total of 9.1 GBq (0.25 Ci) of tritium was discharged to the sanitary sewer. As indicated earlier in this chapter, this release does not include a contribution from SNL / California; LLNL therefore discharged 9.1 GBq (0.25 Ci), an amount that is well within environmental protection standards and is comparable to the amounts reported for the last several years. Moreover, the total tritium released by LLNL in 1997 (and the years from 1992 through 1996) is below the range reported prior to 1992.

Table 6-7. Radioactive liquid effluent releases from the Livermore site, 1988–1997.

	Liquid effluents (GBq)	
Year	^{3}H	^{239}Pu
1988	56	8.1×10^{-4}
1989	59	1.8×10^{-4}
1990[a]	25	2.3×10^{-4}
1991	32	6.1×10^{-4}
1992	8	1.9×10^{-3}
1993	13	2.6×10^{-4}
1994[b]	6.9	1.9×10^{-4}
1995	6.0	1.2×10^{-4}
1996	12	4.2×10^{-4}
1997	9.1	2.1×10^{-4}

Note: The 1996 and 1997 totals for tritium do not include contributions from Sandia National Laboratories/California (SNL/CA); in 1995, SNL/CA ceased all tritium facility operations.

a The 1990 DOE Order 5400.5 required compliance with legally applicable local and state regulations. California Title 17 mandated a 37 GBq (1 Ci) combined limit on the total of all radiation released.

b In 1994, the discharge requirements previously found in Title 17 were changed to correspond to the requirements in Title 10 of the Code of Federal Regulations, Part 20. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci).

Figure 6-3 summarizes the ^{239}Pu monitoring data over the past 10 years. The historical levels observed since 1988 average 1 µBq / mL (3×10^{-5} pCi / mL). These historical levels generally are two-tenthousandths (0.0002) and three-millionths (0.000003) of the DOE DCGs for the soluble and insoluble forms of ^{239}Pu, respectively. The greatest part of the plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge, which is dried and disposed of at a landfill. The median plutonium concentration observed in 1997 sludge (**Table 6-5**), 0.94 mBq / dry g (0.025 pCi / dry g), is approximately

100 times lower than the EPA preliminary remediation goal for residential soil (93 mBq / dry g) and is nearly 400-times lower than the remediation goal for industrial or commercial soil (370 mBq / dry g).

As first discussed in the Environmental Report for 1991 (Gallegos et al. 1992), plutonium and cesium concentrations were slightly elevated during 1991 and 1992 over the lowest values seen historically. As was established in 1991, the overall upward trend was related to sewer cleaning with new, more-effective equipment. During 1993, as utility personnel worked to complete an assessment of the condition of the sewer system, cleaning activity around the site was less extensive, resulting in slightly lower plutonium and cesium concentrations in LLNL effluent. During 1994, in conjunction with the installation of the synthetic sock lining in the sewer system, the cleaning activity around the site was more extensive than in 1993. However, by the end of 1993 the new sewer cleaning equipment had been used on LLNL's entire sewer system; this was reflected in 1994 and the majority of 1995 by the continuation of the slightly lower plutonium and cesium concentrations that were observed in the 1993 effluent.

The plutonium and cesium concentrations in 1996 and the first quarter of 1997 are slightly higher than the concentrations observed in 1993 through 1995, and slightly lower than the observed concentrations of 1990 through 1992, with the exception of a cesium peak early in 1997. This peak, pictured in **Figure 6-3** and reported in **Table 6-5**, is attributable to a controlled release from an LLNL retention tank system and is well below the applicable DOE DCG. The slightly higher plutonium and cesium concentrations of 1996 and the first quarter of 1997 are well below applicable DOE DCG's and remain indicative of well-controlled discharges. The final three quarters of 1997 plutonium and cesium concentrations are comparable to the concentrations observed in 1993 through 1995, and, as such, are also well below the applicable DOE DCGs.

Nonradioactive Pollutants in Sewage

Monitoring Results

Table 6-8 presents monthly average metal concentrations in LLNL's sanitary sewer effluent. The averages were obtained by a flow-proportional weighting of the results from analysis of the weekly composite samples and the 24-hour composites collected each month. Each result was weighted by the total flow volume for the period during which the sample was collected. The results are typical of the values seen during previous years, 1994–1996 (**Figure 6-4**), except for arsenic, mercury and lead

Table 6-8. Average monthly results for metals in LLNL sanitary sewer effluent (in mg/L), 1997 summary.

Month	Ag	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
Jan	0.010	0.29	0.0035	<0.00050	<0.0050	0.016	0.095	1.0	0.00056	0.0054	0.013	0.22
Feb	0.027	0.42	0.0021	<0.00050	0.0050	0.015	0.098	1.3	0.00082	0.017	0.013	0.24
Mar	0.017	0.52	0.010	<0.00050	<0.0050	0.019	0.12	2.1	0.0010	0.024	0.015	0.27
Apr	0.022	0.97	0.0021	<0.00050	<0.0050	0.029	0.16	3.0	0.0016	0.0086	0.024	0.35
May	0.017	0.74	0.0027	<0.00050	0.0052	0.028	0.17	2.4	0.0006	0.0097	0.030	0.33
Jun	0.013	0.60	0.0035	<0.00050	<0.0050	0.015	0.15	1.8	0.0012	0.016	0.036	0.30
Jul	0.016	0.51	0.0024	<0.00050	<0.0050	0.014	0.13	1.3	0.0033	0.0069	0.024	0.26
Aug	0.010	0.58	0.0025	<0.00050	<0.0050	0.013	0.16	1.6	0.0007	0.0081	0.042	0.47
Sep	<0.010	0.65	0.0029	<0.00050	0.0058	0.015	0.13	1.5	0.0012	0.0062	0.039	0.35
Oct	0.009	0.60	0.0035	<0.00044	<0.0044	0.017	0.13	1.4	0.0006	0.0060	0.040	0.29
Nov	<0.010	0.56	0.0045	<0.00050	<0.0050	0.017	0.14	1.6	0.0009	0.0061	0.045	0.37
Dec	<0.010	0.72	0.0051	<0.00050	<0.0050	0.016	0.11	1.9	0.0006	0.0084	0.026	0.29
Median	**0.012**	**0.59**	**0.0032**	**<0.00050**	**<0.0050**	**0.016**	**0.13**	**1.6**	**0.0009**	**0.008**	**0.028**	**0.30**
IQR[a]	**0.007**	**0.13**	**0.0013**	**—[b]**	**—[b]**	**0.003**	**0.04**	**0.6**	**0.0006**	**0.006**	**0.018**	**0.08**
EPL[c]	**0.2**	**—[d]**	**0.06**	**—[d]**	**0.14**	**0.62**	**1.0**	**—[d]**	**0.01**	**0.61**	**0.2**	**3.0**
Fraction of EPL	**0.06**	**—[d]**	**0.05**	**—[d]**	**<0.04**	**0.03**	**0.13**	**—[d]**	**0.09**	**0.01**	**0.14**	**0.10**

Note: Monthly values are presented with less than signs when all weekly and 24-hour composite sample results for the month are below the detectable concentration.

a Interquartile range.

b Because of the large number of nondetects, the interquartile range could not be calculated for these metals. See Chapter 13, Quality Assurance.

c Effluent pollutant limit (LLNL Wastewater Discharge Permit 1996–1997 and 1997–1998).

d No established limit for metal.

results, as discussed in the following section, Environmental Impact. Weekly and 24-hour composite sample concentrations of metals in LLNL sewage are each presented as a percentage of the corresponding effluent pollutant limit (EPL) in **Figures 6-5a** and **6-5b**. The EPL is equal to the maximum pollutant concentration allowed per 24-hour composite sample, as specified by the LLNL wastewater discharge permit. When a weekly sample concentration is at or above 50% of its EPL, the corresponding daily (24-hour composite) samples must be analyzed to determine if any of their concentrations are above the EPL.

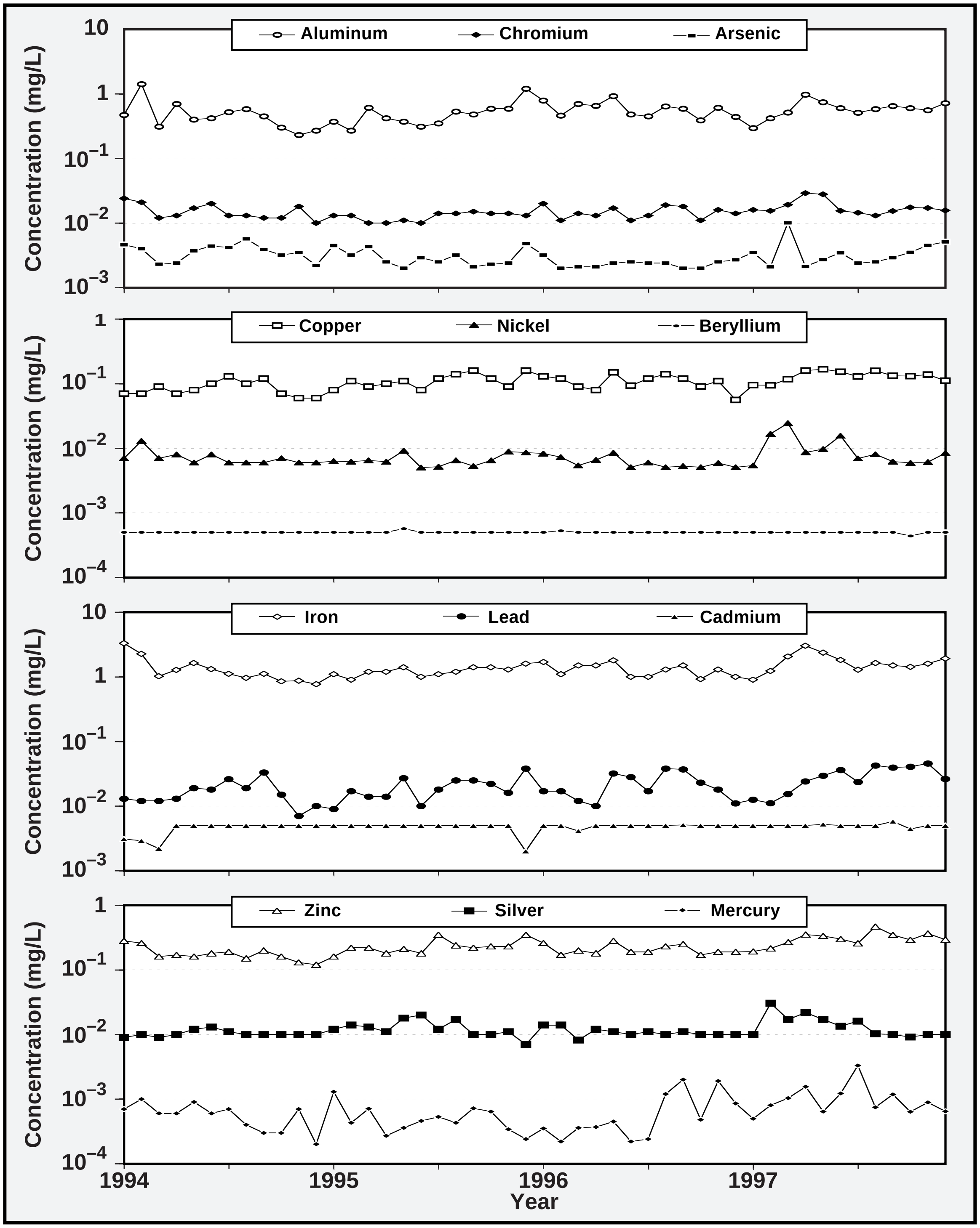

Figure 6-4. Average monthly concentrations of 12 metals in LLNL sanitary sewer effluent showing trends from 1994 through 1997.

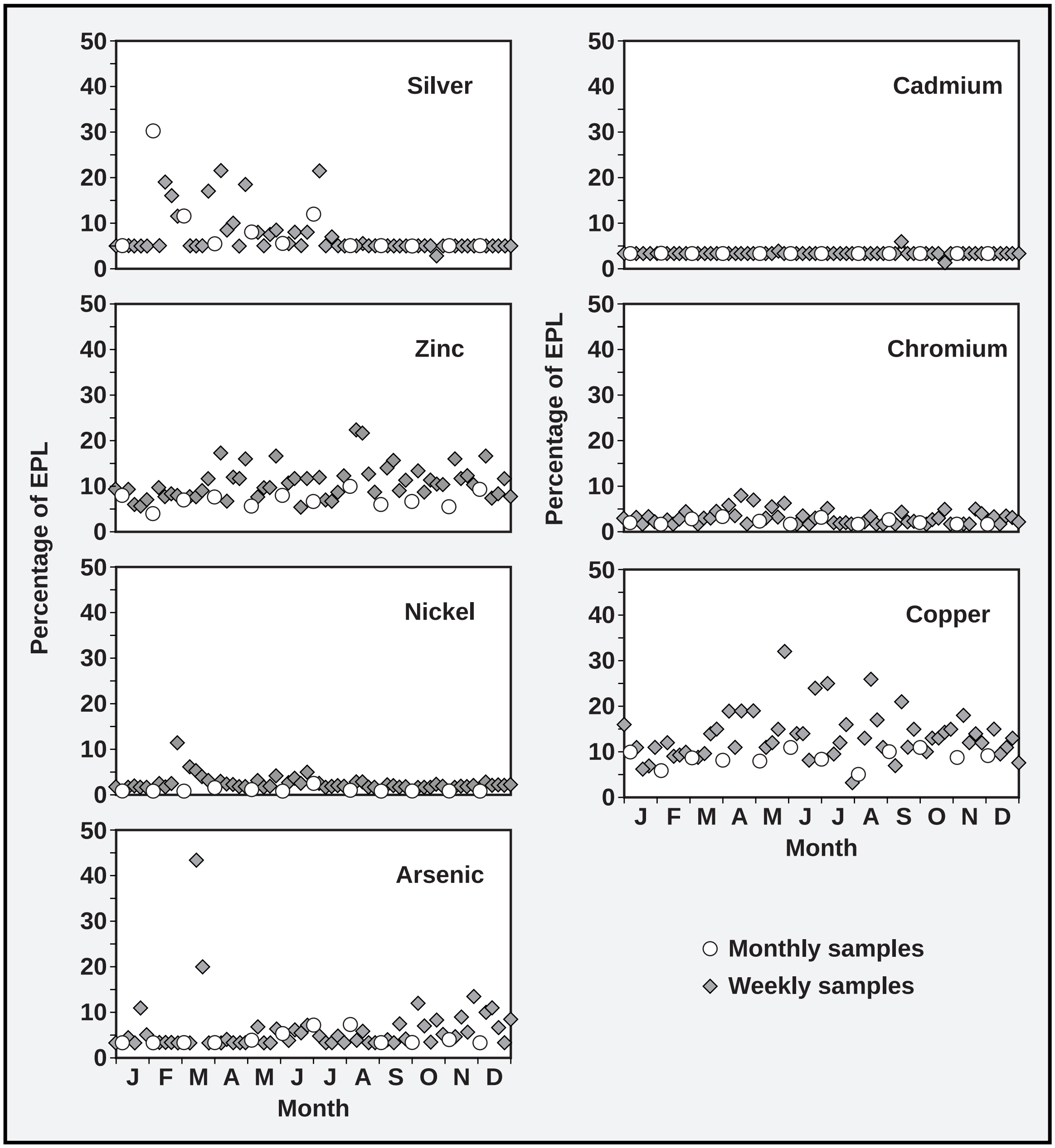

Figure 6-5a. Results as percentages of effluent pollutant limits (EPLs) for 7 of the 9 metals regulated in LLNL sewage.

Detections of anions, metals, and organic compounds and data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 6-9**. Although the samples were analyzed for bromide, nitrite (as N), carbonate

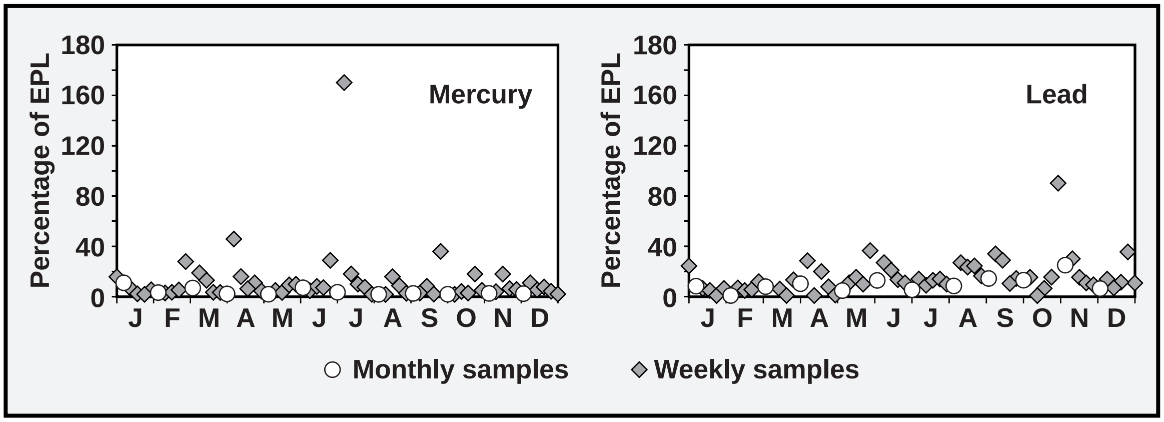

Figure 6-5b. Results as percentages of effluent pollutant limits (EPLs) for 2 of the 9 metals regulated in LLNL sewage.

alkalinity (as $CaCO_3$), hydroxide alkalinity (as $CaCO_3$), the full suite of polychlorinated biphenyls, the full suite of organochlorine pesticides, and cyanide, those analytes were not detected in any sample acquired during 1997, and so are not presented in the table. The results are quite typical of those seen in previous years.

Environmental Impact

At the bottom of **Table 6-8**, the annual median concentration for each metal detected in LLNL's sanitary sewer effluent is compared to the discharge limit. The metals that approached closest to the discharge limits were lead and copper at 14% and 13%, respectively.

Although well below discharge limits, slightly elevated arsenic levels were seen in 1992 through 1995. These levels did not continue in 1996. First discussed in the *Environmental Report 1993* (Gallegos et al. 1994), the elevated arsenic levels were the subject of an extended investigation during 1993, which concluded that the presence of arsenic in the sewer was associated with the ground water cleanup at the gas pad along the southern border of the site. The gas pad cleanup operation was continued in 1994, and the slightly elevated arsenic levels of 1993 continued in 1994. During 1995, the gas pad cleanup operations were reduced, and the elevated arsenic levels were seen less frequently. In 1996, the gas pad operations were concluded, and arsenic levels returned to pre-1992 concentrations. In 1997, gas pad operations were performed separately using portable treatment units, and the arsenic concentrations rose slightly.

Table 6-9. Monthly monitoring results for physical and chemical characteristics of the LLNL sanitary sewer effluent, 1997.

24-hour composite sample parameter (mg/L)	Detection frequency[a]	Minimum	Maximum	Median	IQR[b]
Alkalinity					
Bicarbonate alkalinity (as $CaCO_3$)	12/12	160	230	190	23
Total alkalinity (as $CaCO_3$)	12/12	160	230	190	23
Anions					
Chloride	12/12	41	71	48	10
Fluoride	12/12	0.054	0.16	0.12	0.04
Nitrate (as NO_3)	2/12	<0.5	1.1	<0.5	—
Nitrite (as NO_2)	4/12	<0.5	5.0	<0.5	—
Orthophosphate	12/12	2.3	44	19	16
Sulfate	12/12	12	65	17	12
Nutrients					
Ammonia nitrogen (as N)	12/12	35	82	48	15
Total Kjeldahl nitrogen	12/12	18	110	42	20
Oxygen demand					
Biochemical oxygen demand	12/12	170	730	310	150
Chemical oxygen demand	12/12	110	790	240	210
Solids					
Solid settling rate	12/12	8	70	23	9
Total dissolved solids (TDS)	12/12	130	470	250	48
Total suspended solids (TSS)	12/12	140	520	300	120
Volatile solids	12/12	120	470	250	95
Total metals[c]					
Calcium	12/12	12	22	16	2
Magnesium	12/12	2.4	6.9	3.6	0.6
Potassium	12/12	14	22	17	3
Selenium	2/12	<0.002	0.0040	<0.002	—
Sodium	12/12	26	57	33	5
Total organic carbon	12/12	31	110	62	39
Tributyltin (ng/L)	4/4	56	530	110	190

Table 6-9. Monthly monitoring results for physical and chemical characteristics of the LLNL sanitary sewer effluent, 1997 (concluded).

Grab sample parameters	Detection frequency[(a)]	Minimum	Maximum	Median	IQR[(b)]
Semivolatile organic compounds (μg/L)					
Benzoic acid	2/12	<25	250	<88	—
Benzyl alcohol	6/12	<10	170	<54	—
Bis(2-ethylhexyl)phthalate	4/12	<5	54	<14	—
Diethylphthalate	1/12	<5	50	<10	—
m- and *p*-Cresol	5/12	<5	110	<29	—
o-Cresol	3/12	<5	110	<17	—
Phenol	3/12	<5	<50	<18	—
Total oil and grease (average mg/L)	12/12	13	28	22	6
Total recoverable phenolics (mg/L)	11/12	<0.010	0.10	0.030	0.020
Volatile organic compounds (μg/L)					
Acetone	9/12	<40	400	100	110
Bromodichloromethane	2/12	<1	2.6	<1.0	—
Chloroform	12/12	3.6	16	11	3
Freon 113	4/12	<1	12	<1	—
Tetrachloroethene	1/12	<1	40	<1	—
Trichlorofluoromethane	1/12	<1	3.7	<1	—

a The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

b Interquartile range. Where the detection frequency is less than or equal to 50%, the interquartile range is omitted.

c The 24-hour composite sample results plotted in Figures 6-5a and b and reported in the Data Supplement, Chapter 6 are not reported in this table.

The monthly mercury values continued to reflect the slightly elevated trend that began in mid 1996. However, only one 1997 analytical result exceeded the action level in LLNL's Wastewater Discharge Permit, which states that archived daily composite samples must be analyzed for the pollutant of concern when the result for a weekly composite sample is 50% of, or greater than, the applicable effluent pollutant limit. The mercury analytical result (0.017 mg/L), which exceeded the action level (0.005 mg/L), occurred during July (see **Figure 6-5**). The archived daily samples that corresponded to the appropriate weekly composite sampling period of July 1-7 were submitted for mercury analysis. All of the analytical results for the daily samples were less than the effluent pollutant limit of 0.01 mg/L, with the exception of the result for July 4 of 0.017 mg/L, which exceeded the applicable effluent pollutant limit. The LWRP, the regulatory agency, issued a Notice of Violation (NOV) for the permit exceedance in September 1997. The corrective actions that LLNL has identified are outlined in Chapter 2, **Table 2-10**.

All of the 1997 results for lead were well below the applicable action level and the applicable effluent pollutant limit, with the exception of the October 28 through November 3 weekly composite sample. The lead concentration for this sample (0.18 mg/L) was above the criterion for the action level (0.1 mg/L). LLNL submitted the daily samples for lead analysis. The lead concentrations in two of the samples were slightly above the effluent pollutant limit of 0.2 mg/L. The concentrations in the October 31 and November 1 samples are 0.28 mg/L and 0.25 mg/L, respectively. The other five sample concentrations were below the permit discharge limit of 0.2 mg/L. The LWRP issued an NOV in January 1998, but because of the isolated nature of the discharge, did not suggest or require corrective action. For 1997 as a whole, the monthly lead values presented in **Table 6-8** are slightly higher than those reported in previous years.

Thirteen inadvertent discharges were detected in 1997 by the continuous monitoring system. These incidents did not represent a threat to the integrity of the operations at the LWRP. All of the incidents involved either a metal, an acid, or a base and were reported to the LWRP; LLNL is not permitted by the LWRP to discharge effluent above the effluent pollutant limits specific to each of nine regulated metals or with a pH below 5 or above 10.

Four of the 13 events were metals releases (**Table 6-10**) and the others were pH incidents (**Table 6-11**). Only one of the four inadvertent metals discharges (silver on February 5) resulted in a permit exceedance. Of the nine pH incidents, seven pH discharges below the permit limit of 5 and two were discharges above the permit limit of 10.

Table 6-10. Inadvertent metals discharges detected by the continuous monitoring system in 1997.

Date	Contaminant	Estimated duration (min)[a]	Estimated volume (L)[b]	Daily composite sample concentration (mg/L)	Permit limit (mg/L)
2/5[c]	Silver	20	61,000	0.56	0.2
3/18[c]	Lead	60	15000	0.033	0.2
3/21[c]	Lead	5	1200	<0.002	0.2
11/8[c]	Zinc	100	79,000	0.20, 0.52, 1.6, 0.77[d]	3.0

a For a metal contaminant, the estimated duration corresponds to the duration of the sewer diversion.

b For a metal contaminant, the estimated volume corresponds to the volume of LLNL effluent contained during the sewer diversion.

c All incidents initiated a sewer diversion. All wastewater retained by the sewer diversion facility was later returned to the sanitary sewer system with the exception of contaminated wastewater diverted on February 5 and March 18. The majority of the silver and lead bearing wastewater, contained on February 5 and March 18, respectively, was shipped off site for disposal. With the possible exception of the zinc bearing wastewater contained on November 8, the contaminant concentration of the wastewater returned to the sanitary sewer was only slightly above the EPLs (permission to return this wastewater to the sanitary sewer system was expressly granted by the LWRP). The zinc concentration is not known explicitly for the wastewater retained on November 8; see footnote g in Table 6-11.

d These values are the concentrations for the November 8, 9, 10, and 11 daily composite samples, respectively. The four daily samples submitted for analyses include all sample aliquots collected during the duration of the detected discharge and the return of diverted wastewater to sanitary sewer.

Table 6-11. Inadvertent pH discharges detected by the continuous monitoring system in 1997.

Date	Contaminant	Estimated duration (min)[(a)]	Estimated volume (L)[(b)]	Minimum or maximum pH	Permit limit
2/12[(c,d)]	Acid	8	9600	2.1	5
2/21[(e)]	Base	6	1800	10.1	10
4/7[(e)]	Base	6	1300	10.1	10
8/21[(c,f)]	Acid	14	29000	2.5	5
11/21[(g)]	Acid	1	1000	3.0	5
12/5[(h)]	Acid	15	11000	3.3	5
12/15	Acid	1	1000	4.8	5
12/19[(h)]	Acid	3	3300	3.2	5
12/24[(c,i)]	Acid	8	3100	2.9	5

[a] For an acid or a base contaminant, the estimated duration includes only the time during which the pH of LLNL effluent was below or above the permitted range of 5 to 10, respectively.

[b] For an acid or a base contaminant, the estimated volume includes only the volume of LLNL effluent that was below or above the permitted range of 5 to 10, respectively.

[c] This incident initiated a sewer diversion. All wastewater retained by the sewer diversion facility was later returned to the sanitary sewer. The contaminant concentration of all wastewater returned to the sanitary sewer was within the permitted range for pH.

[d] Based on a high sulfate concentration measured in an instantaneous sample acquired during the incident and the general usefulness of sulfuric acid in work, the most probable cause for this incident is assumed to be sulfuric acid.

[e] LWRP chose not to consider these incidents as enforceable exceedences because they did not exceed the duration criteria of 40 CFR 401.17 and these types of exceedances are not addressed in 40 CFR 403.5.

[f] Based on a high nitrate concentration measured in an instantaneous sample acquired during the incident and the general usefulness of nitric acid in chemical work, the most probable cause for this incident is assumed to be nitric acid.

[g] LWRP choose not to enforce this exceedence.

[h] This incident occurred during regularly scheduled maintenance activities and, consequently, did not initiate a sewer diversion.

[i] Based on a high orthophosphate concentration measured in an instantaneous sample acquired during the incident and the general usefulness of phosphoric acid in chemical work, the most probable cause for this incident is assumed to be phosphoric acid.

As summarized in **Tables 6-10** and **6-11** more than half of the inadvertent discharges warranted sewage diversion. (Unconfined pH and metals releases of sufficient concentration and duration outside of the effluent pollutant limits could disrupt treatment plant operations or cause the treated wastewater to exceed allowable concentration limits for discharge to the San Francisco Bay.) For comparison, 1, 1, 1, 0, and 13 such diversions occurred in 1996, 1995, 1994, 1993, and 1992, respectively. Subsequent analysis of the effluent diverted for pH incidents showed that the average pH was acceptable for release of the wastewater back to the sanitary sewer. All effluent diverted for metals incidents was either returned to the sanitary sewer or shipped off site for disposal.

As a result of several of these incidents, the LWRP issued three Notices of Violation. The first NOV, issued in March 1997, was for silver and pH exceedances on February 5 and 12, respectively. The NOV specifically targeted these two discharges, but treated the pH exceedance as a continuation of low pH exceedances in 1996. A second NOV was issued in October 1997 for the pH exceedance on August 21. The NOV specifically targeted the August 21 discharge, but considered the exceedance as part of a pattern of pH exceedances that began in January 1996. The final NOV, issued in January 1998, was for the four different pH exceedances in December 1997, although these exceedances were considered to be part of the pattern of pH exceedances discussed in the October NOV. Corrective actions taken by LLNL in response to these incidents and their associated NOVs are summarized in Chapter 2, **Table 2-10**.

7

Surface Water

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Introduction

Lawrence Livermore National Laboratory monitors surface water at the Livermore site, in surrounding regions of the Livermore Valley, and at Site 300 and vicinity in the nearby Altamont Hills. At the first two locales, LLNL monitors reservoirs and ponds, the Livermore site swimming pool, the Drainage Retention Basin (DRB), treated ground water discharges, rainfall, tap water, and storm water runoff. At Site 300 and vicinity, surface water monitoring encompasses rainfall, cooling tower discharges, and storm water runoff. The water samples are analyzed for radionuclides, high explosives, total organic carbon, total organic halides, total suspended solids, conductivity, pH, chemical oxygen demand, total dissolved solids, oil and grease, metals, minerals, anions, and a wide range of organic compounds. In addition, fish bioassays are performed annually on water entering and leaving the Livermore site via the Arroyo Las Positas pathway, discharges from the DRB, and water contained in the DRB.

Storm Water

Storm water (runoff water) monitoring is driven by the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991); DOE Order 5400.1, General Environmental Protection Program; DOE Order 5400.5, Radiation Protection of the Public and the Environment; two National Pollutant Discharge Elimination System (NPDES) permits issued under the authority of the Federal Clean Water Act; and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Record of Decision (ROD).

Storm water comes in contact with a large number of potential pollution sources and has the potential to disperse contaminants across broad areas. To evaluate the overall impact of Livermore site and Site 300 operations on storm water quality, storm water flows are sampled where they leave the site. These samples provide information used to evaluate the effectiveness of LLNL's storm water pollution control program. The NPDES permits for storm water (WDR Order No. 95-174, NPDES Permit No. CA0030023 for the Livermore site, and WDR Order No. 94-131, NPDES Permit No. CA0081396 for Site 300) require that LLNL conduct effluent sampling two times per year and conduct visual inspections of the storm drainage system monthly during the wet season, whenever significant storms occur, and twice during the dry season to identify any dry weather flows. Influent sampling is also required at the Livermore site. LLNL monitors up to two more storm events each year (a total of four sampling events) in support of DOE Orders 5400.1 and 5400.5. In addition, annual facility inspections are required to assure that the necessary management measures, known as best management practices (BMPs), are adequate and implemented. The goals of the storm water monitoring program are to demonstrate compliance with permit requirements, aid in implementing the Storm Water Pollution Prevention plans (SWPPPs) (Eccher 1994a and b), and measure the effectiveness of the BMPs in preventing contamination of storm water discharges.

LLNL first monitored storm water runoff at the Livermore site in 1975. The original monitoring network, designed to detect pesticides, was expanded in 1990 to cover new locations and additional water quality parameters (i.e., radioactivity, metals, and additional organic compounds). Additional changes during 1993 complied with the National Pollutant Discharge Elimination System General Industrial Activities Storm Water Permit (NPDES General Permit). In October 1993, also in response to the NPDES General Permit, LLNL established a storm water monitoring program at Site 300. In 1995, the San Francisco Bay Regional Water Quality Control Board (RWQCB) issued a Waste Discharge Requirements and National Pollutant Discharge Elimination System Permit (NPDES Permit No. CA0030023, WDR 95-174) for the Livermore site, which replaced coverage under the Statewide General NPDES Permit for Storm Water Discharges Associated with Industrial Activities (Order No. 91-13-DWQ). The new permit includes specific monitoring and reporting requirements. The current list of analyses requested for storm water samples is given in **Table 7-1**. Flow patterns at the site are such that storm water at sampling locations includes flow from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. Because of this, and because wide-ranging activities are conducted at the Livermore site, it is necessary to analyze storm water for a wide variety of constituents at the Livermore site. In contrast, storm water at Site 300 is sampled at locations that target specific industrial activities, and a smaller range of analyses is sufficient.

Currently, there are no numerical criteria that limit concentrations of specific constituents in storm water effluent. In the federal multisector storm water permit, the Environmental Protection Agency (EPA) established benchmark values for 41 parameters, but stressed that these concentrations (see **Table 7-2**) were not intended to be interpreted as effluent limitations. Rather, they are levels that the EPA has used

Table 7-1. Requested analyses for storm water samples, 1997.

Livermore site	Site 300
pH	pH
Total suspended solids	Total suspended solids
Specific conductance	Specific conductance
Oil and grease	Total organic carbon
Total organic carbon	Gross alpha and beta
Gross alpha and beta	Tritium
Tritium	Uranium
Plutonium	Total organic halides
Chemical oxygen demand	Explosives
General minerals	
Anions	
Metals	
Herbicides—EPA Method 507	
Glycophosphate—EPA Method 547	
Diuron—EPA Method 632	
Fish bioassay (fathead minnow)	

to determine if storm water discharged from any given facility merits further monitoring. Other water quality criteria developed by California and the federal government were used as comparisons with LLNL storm water analytical results in this report. However, these criteria are defined for other purposes, and are therefore not directly applicable to storm water effluent. Nevertheless, use of a broad range of criteria can help to evaluate LLNL's storm water management program and to allow LLNL to ensure high quality in its storm water effluent.

Storm water sample results for the Livermore site were compared with criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin* (San Francisco Bay RWQCB 1995), and results for Site 300 were compared with criteria listed in *The Water Quality Control Plan* (*Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region* (Longley et al. 1994). Criteria in the basin plans include surface water quality objectives for the protection of aquatic life and water quality objectives for waters designated for use as domestic or municipal supply or agricultural supply. These criteria include, by reference, California Maximum Contaminant Levels (MCLs) for drinking water. In addition, results were compared with EPA MCLs and ambient water quality criteria (AWQC), as well as California AWQC. Criteria not specifically listed in the basin plans were obtained from *A Compilation of Water Quality Goals* (Marshack 1995). Criteria are summarized in **Table 7-2**.

Table 7-2. Storm water comparison criteria for constituents of concern at the Livermore site.

Constituent	MCL	AWQC	Benchmark
Radioactive (Bq/L)			
Tritium	740 (EPA)	none	none
Gross alpha	0.56 (EPA)	none	none
Gross beta	1.85 (EPA)	none	none
Elements (mg/L)			
Aluminum	1.0 (CA)	0.75	0.75
Antimony	0.006 (EPA)	0.088	0.636
Barium	1.0 (EPA)	none	none
Beryllium	0.004 (EPA)	none	0.13
Boron	none	none	none
Cadmium	0.005 (EPA)	0.0016[(a)]	0.0159[(b)]
Calcium	none	none	none
Chromium, total	0.05 (CA)	none	none
Chromium(VI)	none	0.015	none
Copper	1.3/1.0 (EPA[(c)]) 0.5 (SF[(d)] Ag[(e)])	0.026[(a)]	0.0636[(b)]
Iron	0.3 (EPA)	none	1.0
Lead	0.15 (EPA)	0.11[(a)]	0.0816[(b)]
Manganese	0.5 (EPA)	none	1.0
Mercury	0.002 (EPA)	0.0024	0.0024
Molybdenum	0.05 (SF[(d)] Ag[(e)])	none	none
Nickel	0.1 (EPA)	2.111[(a)]	1.417[(b)]
Potassium	none	none	none
Selenium	0.05 (EPA)	0.02	0.2385
Silver	0.01 (EPA)	0.0091[(a)]	0.0318[(b)]
Sodium	none	none	none
Thallium	0.002 (EPA)	none	none
Vanadium	0.1 (SF[(d)] Ag[(e)])	none	none
Zinc	5 (EPA)	0.17[(a)]	0.117[(b)]
Miscellaneous (mg/L)			
Bicarbonate alkalinity (as Ca CO_3)	none	none	none
Biochemical oxygen demand (BOD)	none	none	30
Bromide	none	none	none
Carbonate alkalinity (as Ca CO_3)	none	none	none
Chemical oxygen demand	none	none	120

Table 7-2. Storm water comparison criteria for constituents of concern at the Livermore site (concluded).

Constituent	MCL	AWQC	Benchmark
Miscellaneous (mg/L)			
Chloride	250 (EPA)	860	860
Fluoride	1.4 (CA)	none	1.8
	0.8 (SF)		
Nitrate (as NO_3)	45 (EPA)	none	3.01
Nitrate (as N)	10 (EPA)	none	0.68
Nitrate plus nitrite (as NO_3)	45 (EPA)	none	3.01
Nitrate plus nitrite (as N)	10 (EPA)	none	0.68
Nitrite (as N)	1.0 (EPA)	none	0.68
Oil and grease	none	none	15
pH (pH units)	<6.5, >8.5 (EPA)	<6.5, >9.0	<6.5, >9.0
Specific conductance (µmho/cm)	900 (CA)	none	none
Sulfate	250 (EPA)	none	none
Total alkalinity (as $CaCO_3$)	none (EPA)	<20	none
Total dissolved solids (TDS)	500 (CA)	none	none
Total hardness (as Ca CO_3)	none	none	none
Total organic carbon	none	none	2.0
Total suspended solids (TSS)	none	none	100
Organics (µg/L)			
2,4-D	0.07 (EPA)	none	none
2,4,5-T	none	none	none
Acetone	none	none	none
Benzene	1.0 (CA)	none	10
Benzo[*a*] pyrene	0.2 (EPA)	none	none
Bis(2-ethylhexyl)phthalate	4 (EPA)	400	none
Bromacil	none	none	none
Butylbenzylphthalate	none	none	none
Chloroform	100 (EPA)	none	none
Chloromethane	none	none	none
Diazinon	none	0.009	none
Simazine	4 (EPA)	none	none

[a] Hardness dependent; based on receiving water hardness of 160 mg/L.

[b] Hardness dependent benchmark at assumed 100 mg/L $CaCO_3$.

[c] 1.3 is U.S. primary maximum contaminant level (PMCL), not to be exceeded in more than 10% of samples; 1.0 is U.S./CA secondary maximum contaminant level (SMCL).

[d] SF = San Francisco Bay Basin Plan.

[e] Ag = Criteria for agricultural use.

Each LLNL directorate inspected its facilities to verify that the best management practices (BMPs) identified in LLNL's Storm Water Pollution Prevention plans (SWPPPs) were in place, properly implemented, and adequate. LLNL implements BMPs at construction sites and at facilities that use significant materials (as defined by the storm water regulations) to prevent storm water from being contaminated. LLNL submits annual storm water monitoring reports to the San Francisco Bay RWQCB and to the Central Valley RWQCB, reporting the results of sampling, observations, and inspections. Inspections noted a leaking low-conductivity water valve, which was shut off to stop the leak. An oil stain was found near a vacuum pump and cleaned up. Additionally, service vehicles were parking over a storm drain near Building 153. To correct this, striping was added to the area around the storm drain to make it a no parking zone. No other findings or deficiencies at the Livermore site or Site 300 were noted in the annual site inspections.

LLNL also meets the storm water compliance monitoring requirements of the General Construction Activity Storm Water Permit for construction projects disturbing two hectares of land or more. Monitoring for these construction projects included visual observations of sites before and after storms to assess the effectiveness of implemented BMPs. Annual compliance certifications summarize these inspections. The 1997 compliance certifications covered the period of June 1996 through May 1997. During this period, four Livermore site projects were inspected: Building 132 (the new Nonproliferation, Arms Control & International Security building); the Decontamination and Waste Treatment Facility (DWTF); the National Ignition Facility (NIF); and the areas associated with the Soil Reuse Project. One Site 300 project, the Contained Firing Facility (CFF), had obtained permit coverage, but construction had not started. Therefore, no inspections were performed.

As they did in 1996, the San Francisco Bay RWQCB requested submission of compliance status reports for the four Livermore site projects. Since the inception of the General Construction Activity Storm Water Permit, the Central Valley RWQCB has not requested these reports for projects located at Site 300.

The compliance certification for the CFF project noted that no construction had occurred. No compliance issues were noted in the annual compliance certifications for the NIF, Soil Reuse, or DWTF projects. Four compliance issues were noted in the compliance certification of the Building 132 construction:

- A lapse in the inspection program during an interior subcontract package.
- Materials inappropriately left on the construction site, resulting in a spill.
- Commencement of work on a subcontract package prior to the submission and certification of an SWPPP.
- Late preparation of the annual certification.

Building 132 was constructed under eight different subcontractor packages. After the completion of Package Five (an external construction package), internal work (such as the installation of boilers and cabinets) occurred. No materials were stored outdoors. A small area of the site (approximately 0.5 hectare) remained unstabilized. During this period the construction staff was reduced to a minimal level, and storm water inspections were not performed. LLNL will reexamine its construction storm water program and implement procedures to prevent a recurrence of this lapse in the inspection program when there are no subcontractors on the job site. Runoff from this construction site flows into the LLNL Livermore site storm water drainage system and no abnormal discharges were noted in the industrial storm water monitoring program during this period.

On April 15, 1997, LLNL discovered four containers left on the Building 132 construction site. Three of the containers may have been left behind by the subcontractor. Two of the containers were open, filled with rainwater, and had overflowed, depositing an oily water mixture onto the ground. LLNL estimated that approximately 1 L of oily water was released, affecting an area of soil approximately 1.5 m^2. LLNL excavated the affected soil and collected samples to verify the cleanup. Contaminated soil and the drums were disposed of as hazardous waste.

Package Eight, the final exterior construction package, began in May 1997 prior to the subcontractor submitting an SWPPP. This was due to the notice to proceed being issued in advance of the SWPPP submittal. LLNL plans to augment its procurement process to prevent the start of construction prior to submittal and certification of the SWPPP. On June 9, the subcontractor submitted a revision to the project SWPPP that was certified on June 24, 1996; however the subcontractor implemented BMPs and performed inspections from the beginning of construction package in May.

Due to difficulties in obtaining the inspection records from the Package Five subcontractor, the compliance certification was prepared late.

Livermore Site

The natural drainage at the LLNL Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 km to the west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west to eventually merge with Arroyo Mocho (see **Figure 7-1**). An abandoned stream channel is visible on air-photo

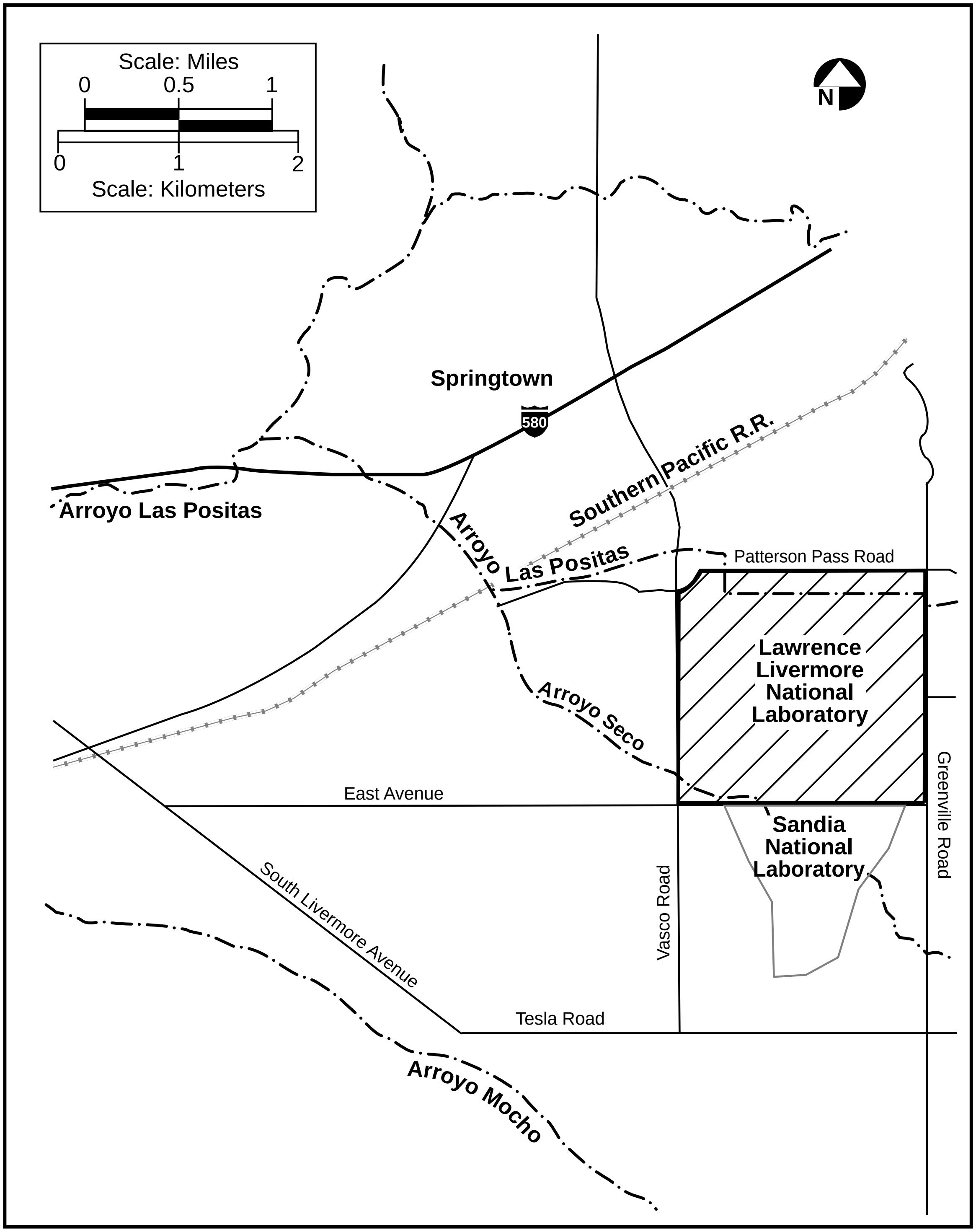

Figure 7-1. Surface water flow in the vicinity of LLNL.

maps of the site east of the present alignment of Arroyo Seco (Carpenter et al. 1984). A Drainage Retention Basin (DRB) was excavated and constructed for storm water diversion and flood control. It collects about one-fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (**Figure 7-2**). This basin was lined to prevent infiltration.

The DRB discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the site drains either directly or indirectly into the two arroyos by way of storm sewers and ditches. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas, diverted from its natural course, follows the northeastern and northern boundaries of the site and exits the site near the northwest corner.

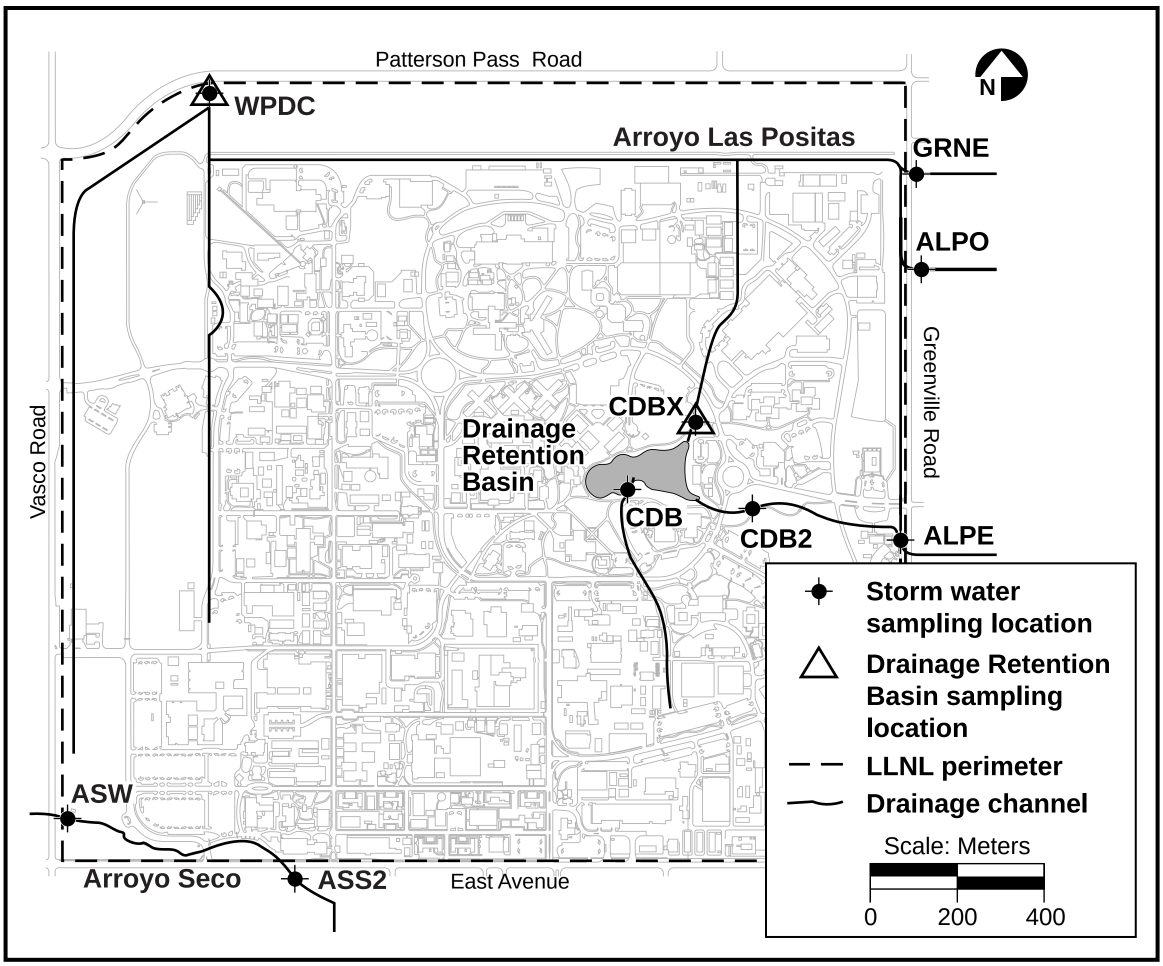

Figure 7-2. Storm water runoff and Drainage Retention Basin (DRB) discharge sampling locations, Livermore site and vicinity, 1997.

Although before 1995 Arroyo Seco and Arroyo Las Positas only flowed when it rained, dry weather observations at the Livermore site noted that water flowed in Arroyo Las Positas throughout 1996 and 1997. This water originated from two sources: natural flow of water from off site that entered LLNL property at the ALPO influent location (**Figure 7-2**), and permitted discharges from on-site ground water treatment facilities.

The Livermore site storm water runoff sampling network consists of nine locations (**Figure 7-2**). Six locations characterize storm water either entering (influent: ALPE, ALPO, GRNE, and ASS2) or exiting (effluent: WPDC and ASW) the Livermore site. Locations CDB and CDB2 characterize runoff from the southeastern quadrant of the Livermore site entering the DRB, and location CDBX characterizes water leaving the DRB. LLNL collected storm water samples at all Livermore site locations on January 15, November 15, and December 8, 1997.

Toxicity Testing. In addition to chemical-specific monitoring, LLNL is required by NPDES permit (WDR 95-174, NPDES Permit No. CA0030023) to conduct acute and chronic fish toxicity testing once per “wet season” (defined as October of one year through April of the following year). In the acute toxicity test, 96-hour survival of fathead minnows (*Pimephales promelas*) in undiluted storm water collected from effluent location WPDC was observed. The San Francisco Bay RWQCB has set a criterion of 20% survival compared with the control as an acceptable level. The testing laboratory provides water to use in the control sample. In addition, in agreement with Regional Board guidance, storm water from influent locations ALPO, ALPE, and GRNE are used as added controls. Thus, a difference of more than 20% between location WPDC and the control sample with the lowest survival is considered a failed test. For example, if survival in the laboratory control is 95%, and survival in water from ALPO, ALPE, and GRNE is 80%, 75%, and 85%, respectively, then survival of less than 55% in WPDC water would be a failed test. If the test is failed, LLNL is required to sample the next runoff event. If two consecutive tests are failed, LLNL is required to perform a toxicity reduction evaluation to identify the source of the toxicity.

In this year’s acute toxicity test (based on the December 8, 1997, sample), 100% of the minnows survived in the WPDC, ALPO, ALPE, and GRNE waters. In addition, a sample for the acute bioassay from location ASS2, LLNL’s influent in the Arroyo Seco pathway, was submitted. Although testing at this location was not required, the results were included for the sake of completeness. Survival in ASS2 water was 90%.

In the chronic test, various dilutions of storm water ranging from 0% storm water (lab control) to 100% (undiluted) storm water are used to determine a dose-response relationship, if any, for both survival and growth of the fathead minnow. No criteria were set by the San Francisco Bay RWQCB for this test; it was performed for information purposes only. Also, because this test was only required at effluent location WDPC, and not conducted with water from corresponding influent locations, there was no way to determine if an effect should be attributed to LLNL or to upstream water quality.

Two samples were collected for chronic toxicity testing in 1997, one on May 23 to fulfill the requirement for the 1996/1997 wet season, and one on December 23 for the 1997/1998 wet season. The samples were collected at location WPDC, the only location where this test was required. Our standard procedure is to use water from the same storm event for both the fish toxicity test and the chemical analyses so that if toxicity is noted, the chemical analyses can aid in identifying the source of the toxicity. However, the chronic fish toxicity test in the spring was not done concurrently with chemical analyses because the testing laboratory was running at capacity and therefore was not able to schedule the test. It was not until the May 23, 1997, storm that LLNL was able to run the chronic toxicity test. (The acute fish toxicity test for the 1996/1997 wet season was conducted in October of 1996.)

For each concentration, four replicates were used, with 10 fish per replicate. Data are summarized in **Table 7-3**. For survival, a 50% no observed effect concentration (NOEC) and 100% lowest observed effect concentration (LOEC) were calculated according to EPA/600/4-91-002. For growth, the EPA calculation returned a value of >50% for both the NOEC and LOEC. The reason for this result seems to be that the dose-response is extremely flat up to and including the 50% dilution. (There is only a 0.03 mg difference between the control and the lowest survival group.) Yet there is a much larger difference (0.2 mg) between the control and the 100% storm water. Therefore, the dose-response curve could not be accurately defined. The results can be interpreted, however, as an NOEC of 50% or more (that is, there is no observed effect at 50%, but the NOEC may be higher) and an LOEC of 100% or less (that is, there is an observed effect at 100%, but the LOEC may be lower). Since no dilutions between 50% and 100% were conducted, further refinement is not possible. Thus, LLNL storm water had an effect on growth at dilutions between 50% and 100%.

For the 1997/1998 wet season, the chronic toxicity test was conducted concurrently with other samples on December 23, 1997. Results are also presented in **Table 7-3**. For this sample, both the NOEC and LOEC for both survival and growth were 100%, indicating that storm water had no effect on survival or growth of the fathead minnow.

Table 7-3. Chronic fish toxicity test results.

Sample concentration (%)	7-day survival		7-day weight	
	Average (%)	Standard deviation	Average (mg)	Standard deviation
5/23/97 (1996/1997 wet season)				
Lab control	100	0	0.72	0.057
5	90	14.1	0.79	0.065
10	98	5.0	0.71	0.074
25	98	5.0	0.71	0.098
50	83	12.6	0.69	0.089
100	83	5.0	0.52	0.047
12/23/97 (1997/1998 wet season)				
Lab control	95	10.0	0.69	0.128
6.25	88	18.9	0.67	0.158
12.5	95	5.8	0.73	0.059
25	98	5.0	0.66	0.074
50	80	28.3	0.57	0.278
100	93	15.0	0.62	0.182

Radioactive Constituents. Storm water tritium, gross alpha, and gross beta results are summarized in **Table 7-4**. Median activities were 10% or less than the respective MCLs. **Figures 7-3** and **7-4** show the historical trend in storm water gross alpha and gross beta, respectively. In these and other storm water historical trend figures in this chapter, all available data for the influent and effluent locations of the two runoff pathways through the Livermore site have been aggregated. Also, data have been aggregated on a wet season basis—that is, October of one year through May of the next—rather than on a calendar year basis. Thus, data on storm plots labeled 96/97 represent October 1996 through May 1997, and data labeled 97 represent October through December 1997. The

Table 7-4. Radioactivity (in Bq/L) in storm water runoff, Livermore site, 1997.

	Tritium	Gross alpha	Gross beta
Median	1.91	0.049	0.191
Minimum	1.24	0.004	0.019
Maximum	358.53	0.154	0.611
Interquartile range	8.34	0.056	0.165
MCL	740	0.555	1.85

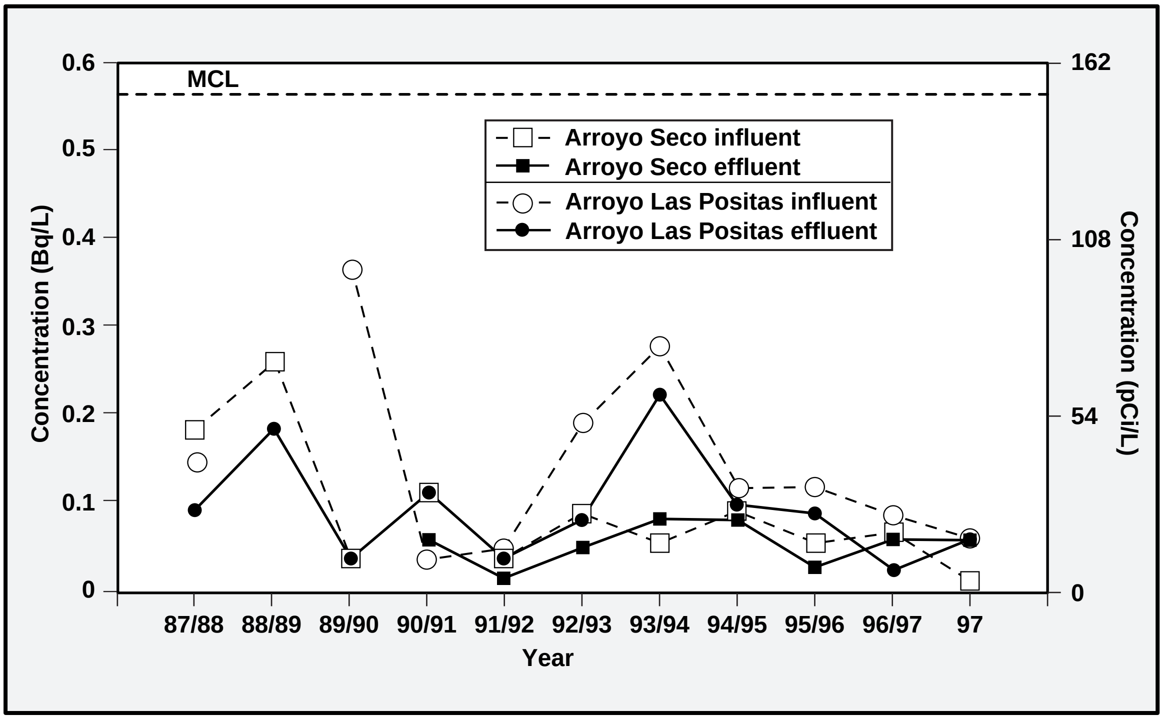

Figure 7-3. Annual median gross alpha in LLNL storm water compared with the maximum contaminant level (MCL).

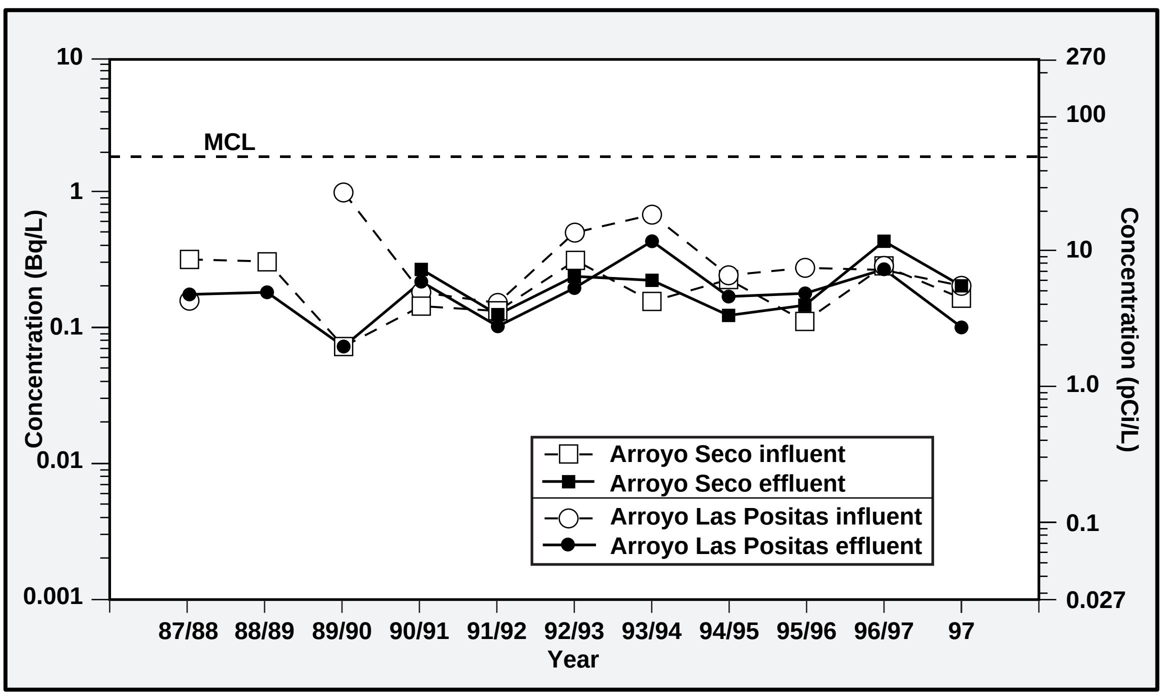

Figure 7-4. Annual median gross beta in LLNL storm water compared with the maximum contaminant level (MCL).

1997 points represent a partial wet season, pending collection of 1998 data, and are based on only one or two sampling events for each location. Finally, plots include all available storm water influent and effluent data for each constituent. The gross alpha and gross beta data show no discernible pattern.

On May 23 at location WPDC, there was a single, higher than typical result for tritium in storm water, 359 Becquerels per liter (Bq/L). The next highest tritium result in storm water was 21.13 Bq/L. The May 23 sampling was a nonroutine sample collection, because the storm occurred outside of the wet season (October 1 of one year through April 30 of the next), as defined by the State Water Resources Control Board. Therefore, influent samples and rain samples were not collected. In response to this single high storm water tritium result, on-site rain monitoring frequency was increased, but no further indication of a tritium source was found. (The highest rainfall tritium level was 65 Bq/L.) In addition, subsequent storm water samples had tritium levels in the low range typically seen in the past several years. Furthermore, although 359 Bq/L is a higher level than that generally seen in LLNL storm water, it is still less than 50% of the MCL for tritium (740 Bq/L).

The historical trend in tritium levels (**Figure 7-5**), which correlates with decreased emissions (see Chapter 5), indicates generally decreasing tritium levels in storm water from a peak in the 1988/1989 season. An exception to the trend is Arroyo Las Positas effluent for the 1996/1997 season and for the fall of 1997. This seems to indicate that the tritium concentration is higher when storm water leaves the site than when it enters the site. However, because "grab sampling" is used, it is not possible to be certain. In grab sampling, a technician is dispatched to the sampling location and manually collects a sample from the flow. The sample therefore represents only a particular point in time during the storm and is generally not representative of the entire flow. More sophisticated, automated methods exist which are capable of sampling during the entire storm event. In addition, the upstream sample and the downstream sample generally do not represent the same portion of the storm. For example, if tritium concentrations fluctuate during the storm event, it would be quite possible to collect an influent sample at a point in the flow during which the concentration is low, and the effluent sample at a point in the flow during which the concentration is high. Nevertheless, additional tritium investigations will be designed for the 1998/1999 rainy season, in order to confirm or contradict the current evidence that effluent tritium concentration is greater than influent tritium concentration, and to identify sources for the higher tritium concentrations, if they are confirmed. These investigations may include:

- Review of site operations to identify potential tritium sources.
- Review of air tritium sampling results.

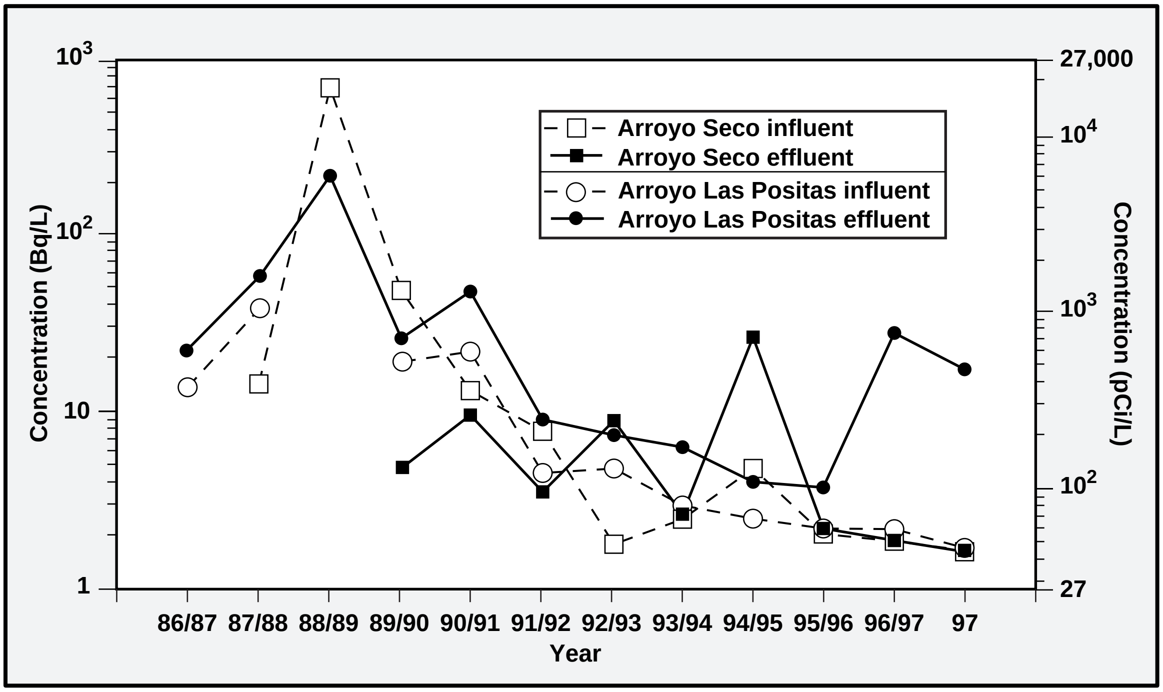

Figure 7-5. Annual median tritium concentrations in LLNL storm water.

- Increased frequency and number of locations of rain sampling.
- Increased frequency and number of locations of storm water sampling.
- Evaluation of tritium concentrations in approved discharges to surface (for example, treated ground water).

Metals Source Identification. Table 7-5 lists nonradioactive constituents found above comparison criteria in Livermore site storm water. (Complete storm water results are presented in Tables 7-2 through 7-4 of the Data Supplement.) Of greatest concern are constituents that exceeded comparison criteria at effluent points, but for which the influent concentrations were less than the corresponding effluent concentrations. The metals identified were aluminum, chromium, copper, iron, lead, manganese, nickel, and zinc. If influent concentrations were greater than effluent concentrations, the source was assumed to be unrelated to LLNL operations, so further analysis was not warranted. Previous historical trend plots indicated that concentrations of some of these constituents were increasing over time. However, further review of the data indicated that the apparent increases were possibly due to a shift from analyses that only recovered dissolved metals, to analyses that recovered the total metal concentrations (dissolved plus suspended) in the water. Due to ambiguities in past laboratory practices, it is difficult to determine explicitly which type of analysis (dissolved or total)

Table 7-5. Nonradioactive constituents above comparison criteria (see **Table 7-2**) in storm water runoff, Livermore site, 1997.

Parameter	Storm date	Dissolved or total	ALPE	ALPO	ASS2	ASW	CDB	CDB2	CDBX	GRNE	WPDC
Metals (mg/L)											
Aluminum	1/15	Dissolved				0.78					
		Total							3.7		3.8
		Total							4		3.8
	11/15	Total	14	5.9	5.3	60	6.3	14		70	15
		Total	9.9	0.76	1.4	6.5	1.7	2.4		7.4	2.6
	12/8	Total	3	7.3	2.3	8.1	3	5.6	1.1	5.2	7.3
		Total	2.8	7	1.2	4.8	2.1	5.1	1.5	6.1	5.2
Chromium	11/15	Total	0.024		0.017	0.11	0.016	0.032		0.1	0.021
	12/8	Total				0.018				0.017	0.016
Copper	11/15	Total	0.029			0.12		0.031		0.059	
		Total								0.059	0.029
Iron	1/15	Dissolved	0.46					0.39	0.41		
		Total							3.2		3.2
		Dissolved	0.57	0.37	0.42	0.62		0.39	0.36		0.35
		Total							3.3		3.2
	11/15	Total	11	5.2	5.9	63	5.8	13		62	15
		Total	9.6	1	1.6	5.6	1.8	2.3		5.4	2.7
	12/8	Total	2.6	6.7	2.3	10	3	5.2	1.3	5.1	7.9
		Total	2.4	6.3	1.3	6.6	2.5	5.0	1.7	6.3	5.9
Lead	11/15	Dissolved									
		Total				0.064				0.026	
Manganese	11/15	Total				1.3					
		Total				1				0.84	0.27
Nickel	11/15	Total				0.13				0.11	
		Total								0.113	
Vanadium	11/15	Total		0.13							
Zinc	11/15	Total			0.14	0.46	0.18	0.17		0.34	0.35
		Total			0.13	0.47	0.18	0.15		0.25	0.24
	12/8	Total				0.15	0.17				0.17
		Total				0.22	0.17				0.24

Table 7-5. Nonradioactive constituents above comparison criteria (see **Table 7-2**) in storm water runoff, Livermore site, 1997 (continued).

Parameter	Storm date	Dissolved or total	ALPE	ALPO	ASS2	ASW	CDB	CDB2	CDBX	GRNE	WPDC
Miscellaneous (mg/L)											
Chemical oxygen demand	1/15	Total				122					
	12/8	Total	128								
Chloride	12/8	Total	700					282			
	12/8	Total	700					312			
Fluoride	1/15	Total		0.88							
	12/8	Total	1								
	1/15	Total		0.89							
	12/8	Total	1								
Nitrate (as N)	1/15	Total		2.6	3.5	3.5				3	1.2
		Total									1.2
	11/15	Total	1.2		1.1		0.79	0.77		4.9	
	12/8	Total		2.1	0.74	0.8	0.77	0.68	0.74	8.9	1.3
	1/15	Total	0.2	2.6	3.4	3.5	0.5	0.2	0.6	2.4	1.2
	11/15	Total	1	0.79	1	0.39	0.7	0.77		4.9	0.53
	12/8	Total		2			0.77		0.74	8.6	1.3
Nitrate (as NO_3)	1/15	Total		11.5	15.5	15.5				13.3	5.3
		Total									5.3
	11/15	Total	5.3	3.7	4.9		3.5	3.4		22	
	12/8	Total		9.3	3.3	3.5	3.4		3.3	39	5.8
	1/15	Total		11.5	15.1	15.5				10.6	5.3
	11/15	Total	4.4	3.5	4.4		3.1	3.4		22	
	12/8	Total		8.9			3.4		3.3	38	5.8
Sulfate	12/8	Total	580				254				
Total alkalinity (as $CaCO_3$)	1/15	Total					11.4				
	11/15	Total			14	14	12	19			
	12/8					15					

Table 7-5. Nonradioactive constituents above comparison criteria (see **Table 7-2**) in storm water runoff, Livermore site, 1997 (concluded).

Parameter	Storm date	Dissolved or total	ALPE	ALPO	ASS2	ASW	CDB	CDB2	CDBX	GRNE	WPDC
Miscellaneous (mg/L) (cont'd)											
Total dissolved solids (TDS)	1/15	Total		890	740	735					
	11/15	Total		705							
	12/8	Total	2420					1020			
Total suspended solids (TSS)	1/15	Total		125	606	612		191			
	11/15	Total	155	139		978		150		1150	204
	12/8	Total				306				174	121
General indicator parameters											
pH (pH units)	11/15	Total			6.45						
Specific conductance (µmho/cm)	1/15	Total		1420	1090	1060					
	11/15	Total		1200							
	12/8	Total	3810					1670			
EPA Method 507 (µg/L)											
Simazine	11/15	Total		7.5						6.8	
	12/8	Total		71		8.3				6	6.7

was used in the historical record. During the 1997/1998 rainy season, source investigations were conducted to determine how much of these metals were present in the liquid (dissolved) and how much in sediments (suspended) were being transported during storm water flow events. The source identification study also evaluated how much of the loading in each fraction (dissolved and suspended) originates off site, and how much is contributed by on-site sources. Finally, the study related concentrations of constituents in storm water from a particular storm and location to the concentration of total suspended solids from the same storm and location. To accomplish these goals, samples for applicable constituents were collected in duplicate. One sample was analyzed for total concentration (i.e., dissolved and suspended) of the constituents of interest. The second sample was passed through a 0.45-µm filter in order to evaluate the dissolved component. Although particles smaller than 0.45 µm (i.e., not dissolved) will of course pass through this filter, this removes the majority of the sediments, and is therefore adequate for evaluation of the dissolved fraction of the storm water. Preliminary results of the source identification have confirmed that the apparent increasing trend in concentrations is due to a shift from analyses that recover the dissolved fraction to analyses that recover total concentrations. For example, total concentrations were often much higher than dissolved concentrations (see **Table 7-6**). In addition, exceedances noted at the Arroyo Seco effluent location (ASW) were attributed to samples with high sediment load. Because half of the data for this source investigation were collected in 1998, the full analysis will be presented in the 1998 Site Annual Environmental Report.

Table 7-6. Annual median values for dissolved and total concentrations of selected metals.

Metal (mg/L)	Dissolved or total	Arroyo Las Positas		Arroyo Seco	
		Influent	Effluent	Influent	Effluent
Chromium	Dissolved	0.0013	0.0014	<0.001	<0.001
	Total	0.0061	0.016	0.01085	0.064
Copper	Dissolved	0.0085	0.0081	0.0095	0.0075
	Total	0.017	0.015	0.01565	0.0715
Iron	Dissolved	<0.05	<0.05	<0.05	0.072
	Total	5.85	4.55	1.95	8.3
Zinc	Dissolved	0.016	0.059	0.0505	0.043
	Total	0.0495	0.205	0.1045	0.34

Other Nonradiological Parameters. Other nonradiological parameters, which were above comparison criteria (see **Table 7-5**) and for which influent concentrations were lower than effluent concentrations, were chemical oxygen demand, simazine, and total suspended solids.

A number of other constituents in LLNL runoff were also above comparison criteria. In every case, however, when the concentration exceeded a criterion at an effluent point, there was a corresponding influent point with a higher concentration, indicating an off-site or possibly naturally occurring source. These constituents were chloride, fluoride, nitrate, sulfate, total dissolved solids, pH, specific conductance, and vanadium. Organics detected (but not above criteria) in 1997 LLNL runoff were benzo[*a*]pyrene, bromacil, diazinon, diethylhexylphthalate, and diuron.

Site 300

The topography of Site 300 is much more irregular than that of the Livermore site; steep hills and ridges oriented along a generally northwest/southeast trend are separated by intervening ravines. The elevation ranges from approximately 150 m above sea level at the southeast corner of the site to approximately 538 m in the northwestern portion.

Surface water at Site 300 consists of seasonal stream runoff, springs, and natural and man-made ponds. The primary drainage in the Site 300 area is Corral Hollow Creek, an ephemeral stream that borders the site to the south and southeast. No continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainageway for most of Site 300; it extends from the northwest portion of the site to the east-central area. Corral Hollow Creek and Elk Ravine drain eastward to the San Joaquin River Basin. Some smaller canyons in the northeast portion of the site drain to the north and east toward Tracy. A small portion of Site 300 drains to Alameda County before flowing into Corral Hollow Creek, but is not included in the storm water sampling because there are no industrial activities in the associated drainages.

There are at least 23 springs at Site 300. Nineteen are perennial, and four are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation. Vegetation surrounding the springs includes cattails, nettles, willows, and grass. Only three of the springs have flow rates greater than 4 L/min. The significance of individual springs is discussed in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, hereafter referred to as the Final SWRI Report (Webster-Scholten 1994). A vernal pool is present in the northwest corner of Site 300. It is a seasonal pool created by ponding of water in a natural depression.

A number of surface water bodies are present at Site 300 and vicinity. A sewage evaporation pond and a sewage percolation pond are located in the southeast corner of the site in the General Services Area (GSA), and two lined high explosives (HE) process water impoundments are located to the west in the Explosives Process Area. (Monitoring associated with these facilities is contained in Chapter 8.) There is a pond in the residence area of the Carnegie State Vehicular Recreation Area located off site just east of Pit 6 at the mouth of Middle Canyon. In addition, four small off-site stock watering ponds are present just north of Site 300.

Other surface water flow at Site 300 results from blowdown water from cooling towers in the East Firing Area, the West Firing Area and other areas. Cooling tower discharges and their potential impact are discussed in the Final SWRI Report (Webster-Scholten 1994).

The Site 300 storm water sampling network began in 1994 with six locations and now consists of eight locations (**Figure 7-6**). Location CARW is used to characterize runoff in Corral Hollow Creek upgradient and therefore unaffected by Site 300 activities. Location GEOCRK is used to characterize runoff in Corral Hollow Creek, downgradient of Site 300. The remaining locations were selected to characterize storm water runoff at locations that could be affected by specific Site 300 activities.

LLNL procedures specify sampling of a minimum of two storms per rainy season from Site 300. For the 1996/1997 rainy season, samples were collected on October 29, 1996, and January 2, 1997, while for the 1997/1998 rainy season, all samples were collected in 1998. Therefore, only one storm was sampled in 1997 (**Table 7-7**). Typically, a given

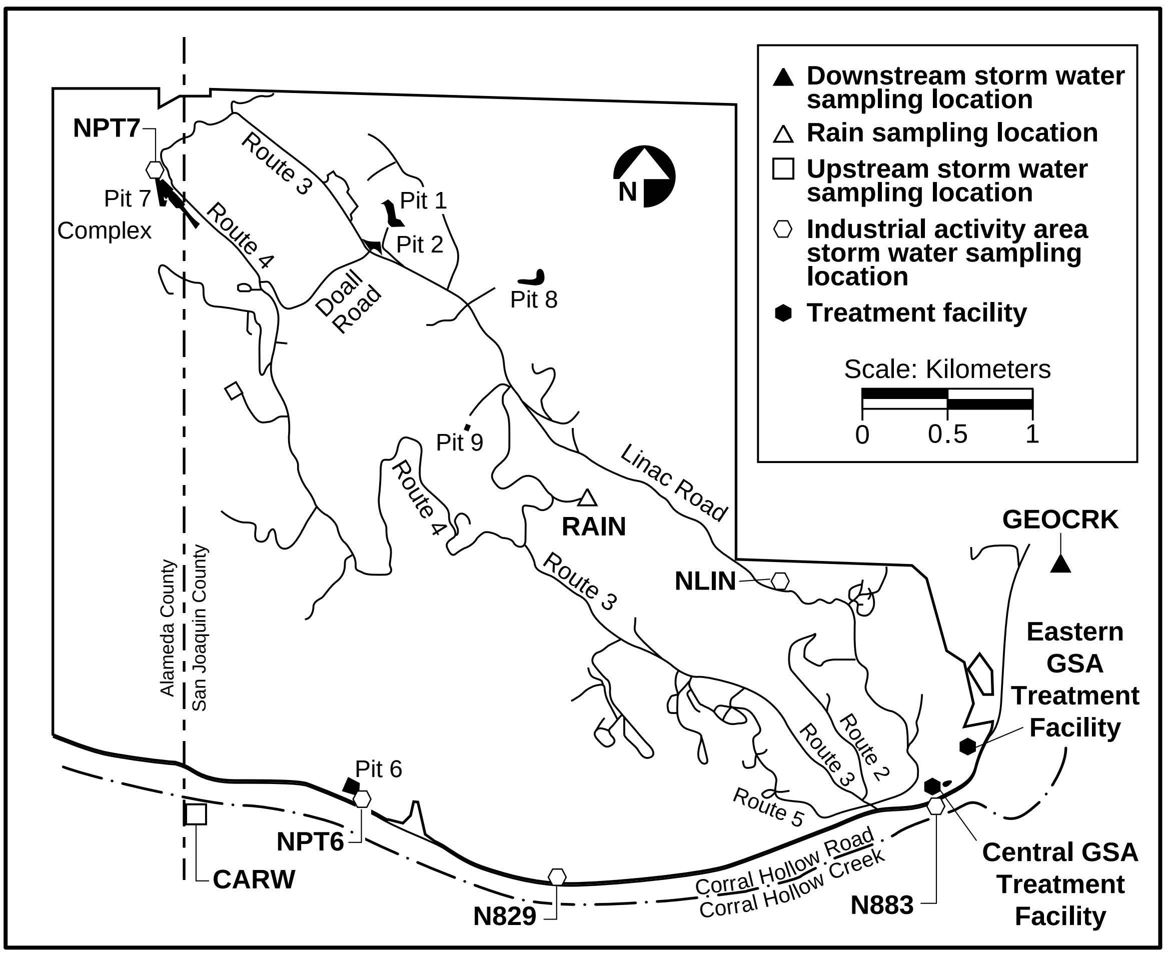

Figure 7-6. Rain and storm water runoff sampling locations, Site 300 and vicinity, 1997.

storm will not produce runoff at all Site 300 locations because Site 300 receives relatively little rainfall and is largely undeveloped. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff occurs.

The maximum tritium concentration in Site 300 storm water was 2.44 Bq/L (**Table 7-7**), or 0.3% of the 740 Bq/L MCL (see **Table 7-2**). Maximum gross alpha and gross beta were 0.27 and 0.47 Bq/L, respectively, approximately 50% and 25% of their MCLs (0.56 and 1.85 Bq/L). Although total suspended solids, or TSS (**Table 7-7**), were above the EPA benchmark (100 mg/L) (see **Table 7-2**) at on-site location N883 (307 mg/L), they were well below concentrations at the off-site upstream locations NSTN and CARW (2010 and 1500 mg/L, respectively). Total suspended solids downstream of Site 300 at location GEOCRK (1530 mg/L) were also less than concentrations at the off-site upstream locations. Historically, background total suspended solids have been as high as 20,000 mg/L, indicating that these values are due to erosion typical of the region. All other nonradioactive parameters were below comparison criteria.

Table 7-7. Analysis for Site 300 storm water runoff, 1997.[(a)]

Parameter	CARW	GEOCRK	N883	NPT7	NSTN
Radioactive (Bq/L)					
Tritium	2.42 ± 2.42	2.33 ± 2.33	2.44 ± 2.44	2.39 ± 2.39	2.42 ± 2.42
Gross alpha	0.23 ± 0.052	0.27 ± 0.067	0.019 ± 0.023	0.020 ± 0.025	0.19 ± 0.048
Gross beta	0.35 ± 0.074	0.47 ± 0.085	0.10 ± 0.063	0.077 ± 0.074	0.29 ± 0.081
Uranium-234	0.027 ± 0.0067	0.060 ± 0.010	0.0011 ± 0.0037	0.016 ± 0.0052	0.029 ± 0.0067
Uranium-235	0.0037 ± 0.003	0.0030 ± 0.0033	-0.0004 ± 0.0022	0.0011 ± 0.0022	0.00074 ± 0.0026
Uranium-238	0.026 ± 0.0067	0.060 ± 0.01	0.0033 ± 0.0037	0.013 ± 0.0048	0.018 ± 0.0052
Nonradioactive					
Total organic carbon (mg/L)	11.7	11.9	6.4	3.3	11.3
Total suspended solids (mg/L)	1500	1530	307	26.5	2010
pH (pH units)	8.14	8.24	7.04	8.18	8.1
Specific conductance (µmho/cm)	322	487	27	149	323
Total organic halides (µg/L)	<20	<20	<20	<20	<20

a All samples taken on January 2, 1997.

Rainfall

Livermore Site

Rainfall is sampled for tritium according to written procedures in Appendix A of the *Environmental Monitoring Plan* (Tate et al. 1995). Historically, the tritium activity measured in rainfall in the Livermore Valley has resulted primarily from atmospheric emissions of tritiated water vapor (HTO) from stacks at LLNL's Tritium Facility (Building 331), and Sandia National Laboratories / California's former Tritium Research Laboratory. The Building 343 rain sampling location is near the Tritium Facility (Building 331), where LLNL personnel have reduced operations in recent years and performed significant inventory reduction and cleanup activities. The total measured atmospheric emission of HTO from LLNL facilities in 1997 was 9.8 Terabecquerels (TBq), equal to 267 curies (Ci) (see Chapter 5, Air Monitoring).

The rain sampling station locations are shown on **Figure 7-7.** The fixed stations are positioned to record a wide spectrum of tritium activities in rainfall, from the maximum expected down to background levels.

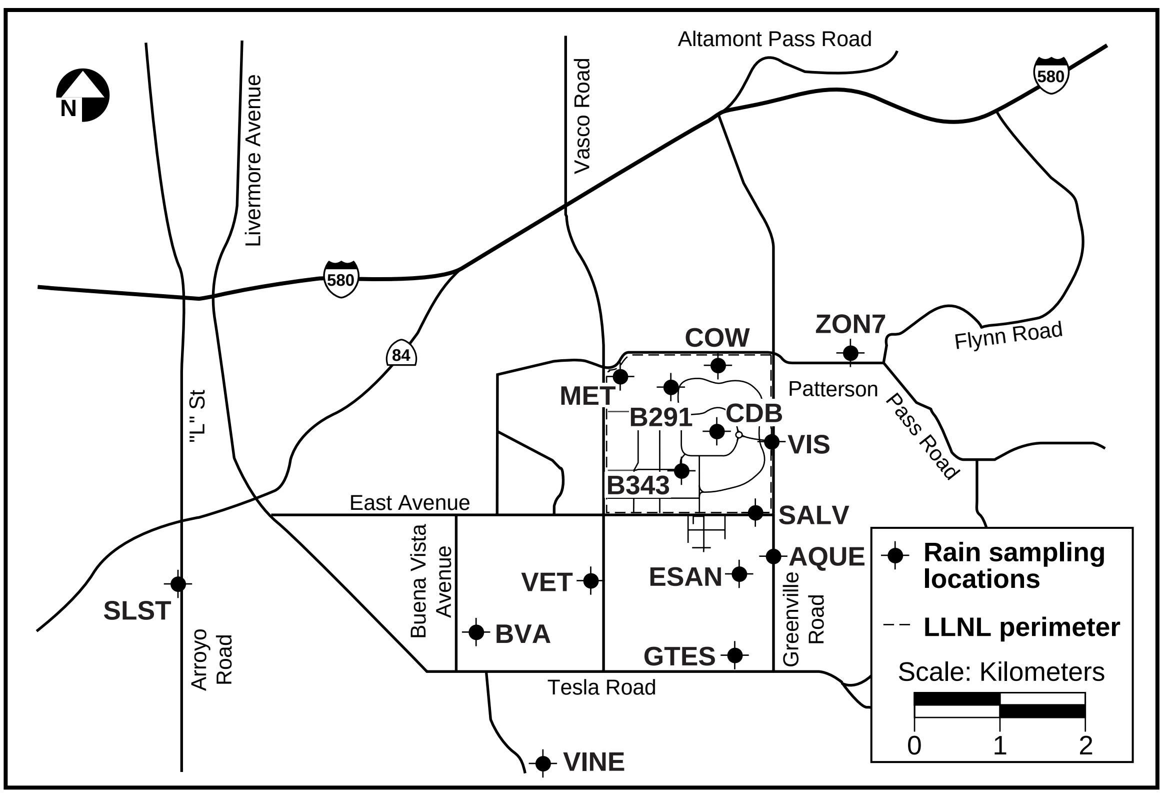

Figure 7-7. Rain sampling locations, Livermore site and Livermore Valley, 1997.

LLNL collected rainfall samples eight times in 1997. Complete data are shown in Table 7-5 of the Data Supplement. The Livermore site rainfall has exhibited elevated tritium activities in the past (Gallegos et al. 1994). During 1997, however, measurements of tritium activity in rainfall were all far below the 740 Bq/L (20,000 pCi/L) MCL established by the EPA for drinking water. The highest overall activity was 65 Bq/L (see **Table 7-8**) measured on November 20, 1997, near Building 343, just to the north of the on-site Tritium Facility. This value is approximately 9% of the MCL for tritium. The highest off-site activity was 7 Bq/L, recorded in a sample collected from station VET on January 15, 1997.

Tritium activity in rainfall at the Livermore site has decreased during the past eight years. This decrease mirrors the downward trend in total HTO emissions from LLNL's Tritium Facility and the closure of SNL/California's former Tritium Research Laboratory. These trends are shown in **Figure 7-8**. Values for median tritium activity are derived from the six on-site rain sampling locations (Building 343, Building 291, CDB, SALV, VIS, and COW) that historically have given the highest activities. A more than threefold decrease in total HTO emissions has occurred since 1990, down from 34.9 TBq (943 Ci) to 9.8 TBq (267 Ci). This decrease is mirrored by a more than tenfold decrease in median tritium activity measured in rainfall on site at LLNL: down from 65.9 Bq/L (1780 pCi/L) to 3.85 Bq/L (104 pCi/L).

Table 7-8. Tritium activities (in Bq/L) in rainfall for the LLNL Livermore site and the Livermore Valley.

	Livermore site	Livermore Valley	Overall
Median	3.85	1.81	2.51
Maximum	65.12	9.73	65.12
Minimum	1.23	0.89	0.89
Interquartile range	7.86	1.42	4.06
Number of samples	54	24	78

Site 300

One central location is used to collect rainfall for tritium activity measurements at LLNL's Experimental Test Site, Site 300 (**Figure 7-6**). Rainfall is composited (added together) for each month and analyzed when there is sufficient volume. During 1997, samples were analyzed for January, March, November, and December, with tritium activities of 1.45, 1.38, 1.21, and 1.28 Bq/L, respectively. Over the past 25 years, 160 measurements of rainfall samples collected at this location give a maximum tritium activity of only 9.1 Bq/L. The tritium activity measured in rainfall at Site 300 has been indistinguishable from atmospheric background levels over the past 25 years.

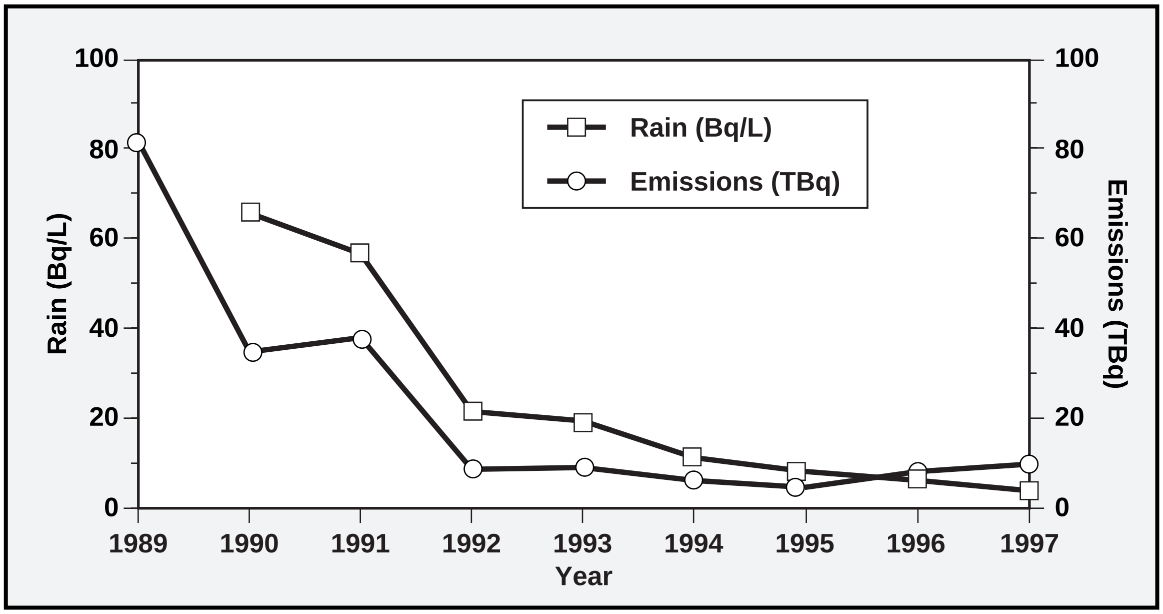

Figure 7-8. Trends of median tritium activity in rain and total stack emissions of HTO from the LLNL Livermore site and SNL/California, 1990 to 1997. (Emissions in 1996 and 1997 are only from LLNL.)

Livermore Site Drainage Retention Basin

The Drainage Retention Basin (DRB) was constructed and lined in 1992 after remedial action studies indicated that infiltration of storm water from the existing basin increased dispersal of ground water contaminants. Located in the center of the Livermore site, the DRB can hold approximately 53 ML (43 acre-feet) of water.

After the basin was lined, LLNL adopted the *Drainage Retention Basin Management Plan* (The Limnion Corporation 1991). The focus of the management plan was to implement a long-term biological monitoring and maintenance program and to address water quality problems by bioremediation and nutrient load reduction. The management plan identified two water sources to fill and maintain the level of the DRB. The primary water source was intended to be water reclaimed from ground water treatment units and discharged to the basin either through the existing storm water collection system or piped directly to the DRB. The secondary water source was intended to be storm water runoff. However, since the start of operation in 1992, storm water runoff has been the primary source of water entering the DRB. In 1997, treated ground water began significantly contributing to the dry weather flow into the DRB with occasional discharges from Treatment Facility D, Treatment Facility E-East, and portable treatment units (PTUs).

The San Francisco Bay RWQCB regulates discharges from the DRB according to the Livermore site CERCLA Record of Decision (ROD), as modified by the Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory, Livermore site (Berg, 1997c). The CERCLA ROD establishes discharge limits for all remedial activities at the Livermore site. In 1992, LLNL developed a sampling program for the DRB, which was approved by the San Francisco Bay RWQCB. The program consists of sampling discharges from the DRB (location CDBX) and the corresponding site storm water outfall (location WPDC) during the first release of the rainy season from the DRB and a minimum of one additional storm (chosen in conjunction with storm water runoff monitoring). This sampling plan was modified in a letter to the San Francisco Bay RWQCB dated December 9, 1997, modifying analytes and including a dry season sampling plan. Discharge sampling locations CDBX and WPDC are shown in **Figure 7-2**. Samples are collected at CDBX to determine compliance with discharge limits. Sampling at WPDC is done to identify any change in water quality as DRB discharges travel through the LLNL storm water drainage system and leave the site. Effluent limits for discharges from the DRB, applied at CDBX, are found in **Table 7-9**.

By agreement with the San Francisco Bay RWQCB, every quarter LLNL submits a report summarizing weekly, monthly, quarterly, semiannual, and annual monitoring of the basin as specified in the *Drainage Retention Basin Management Plan* (The Limnion Corporation 1991). Sampling to determine whether water quality management objectives are met is conducted at several points within the DRB. Dissolved oxygen (DO) content and temperature are measured at eight locations (**Figure 7-9**). Because of limited variability among sampling locations, all samples, other than those for DO and temperature, are routinely collected from CDBE, located at the middle depth of the DRB. The routine management constituents are identified in **Table 7-10**. LLNL requested and the San Francisco Bay RWQCB approved changes to the analytes monitored at the DRB in a letter dated December 9, 1997. These changes were implemented in 1998.

During 1997, discharges from the DRB were sampled four times. Three discharges were wet season discharges and one discharge occurred during the dry season. For purposes of determining discharge monitoring requirements and frequency, the wet season is defined in the December 9, 1997, letter as October 1 through May 31, the period when rain-related discharges usually occur. All discharges were below the discharge limits.

Table 7-9. Treated ground water and Drainage Retention Basin discharge limits identified in CERCLA ROD as amended for outfalls CDBX, TFB, TFC, TFD, TFE, TFF, TFG, TF406, and TF518.

Constituent	Effluent discharge limits	
	Dry season Apr 1–Nov 30	Wet season Dec 1–Mar 31
Metals (μg/L)		
Antimony	6	not applicable[a]
Arsenic	50	10
Beryllium	4	not applicable[a]
Boron	not applicable[b]	not applicable[a]
Cadmium	5	2.2
Chromium (total)	50	not applicable[a]
Chromium(VI)	not applicable[b]	22
Copper	1300	23.6
Iron	not applicable[b]	not applicable[a]
Lead	15	6.4
Manganese	not applicable[b]	not applicable[a]
Mercury	2	2
Nickel	100	320
Selenium	50	10
Silver	100	8.2
Thallium	2	not applicable[a]
Zinc	not applicable[b]	220
Organics (μg/L)		
1,1-Dichloroethane	5	5
1,1-Dichloroethene	5	5
1,2-Dibromoethane	0.02	0.02
1,2-Dichloroethane	5	5
Base/neutral and acid extractable compounds and pesticides	5	5
Benzene	0.7	0.7
Carbon tetrachloride	5	5
cis-1,2-Dichlorethene	5	5
Ethyl benzene	5	5
Polynuclear aromatic hydrocarbons	15	15
Tetrachloroethene	4	4
Toluene	5	5
Total petroleum hydrocarbons	50	50
Total trihalomethanes	5	5
trans-1,2-Dichloroethene	5	5
Trichloroethene	5	5
Vinyl chloride	2	2
Volatile organic compounds (total)	5	5
Xylenes (total)	5	5

Table 7-9. Treated ground water and Drainage Retention Basin discharge limits identified in CERCLA ROD as amended for outfalls CDBX, TFB, TFC, TFD, TFE, TFF, TFG, TF406, and TF518 (concluded).

Constituent	Effluent discharge limits	
	Dry season Apr 1–Nov 30	**Wet season Dec 1–Mar 31**
Physical		
pH (pH units)	6.5 to 8.5	6.5 to 8.5
Toxicity		
Aquatic survival bioassay (96 hours)	Median of 90% survival and a 90 percentile value of not less than 70% survival for 96-hour bioassay.	Median of 90% survival and a 90 percentile value of not less than 70% survival for 96-hour bioassay.
Radioactivity		
Tritium	740 Bq/L	740 Bq/L

[a] No limit is established for aquatic life protection; however, aquatic life is protected by bioassay analysis.

[b] No MCL is established for this metal.

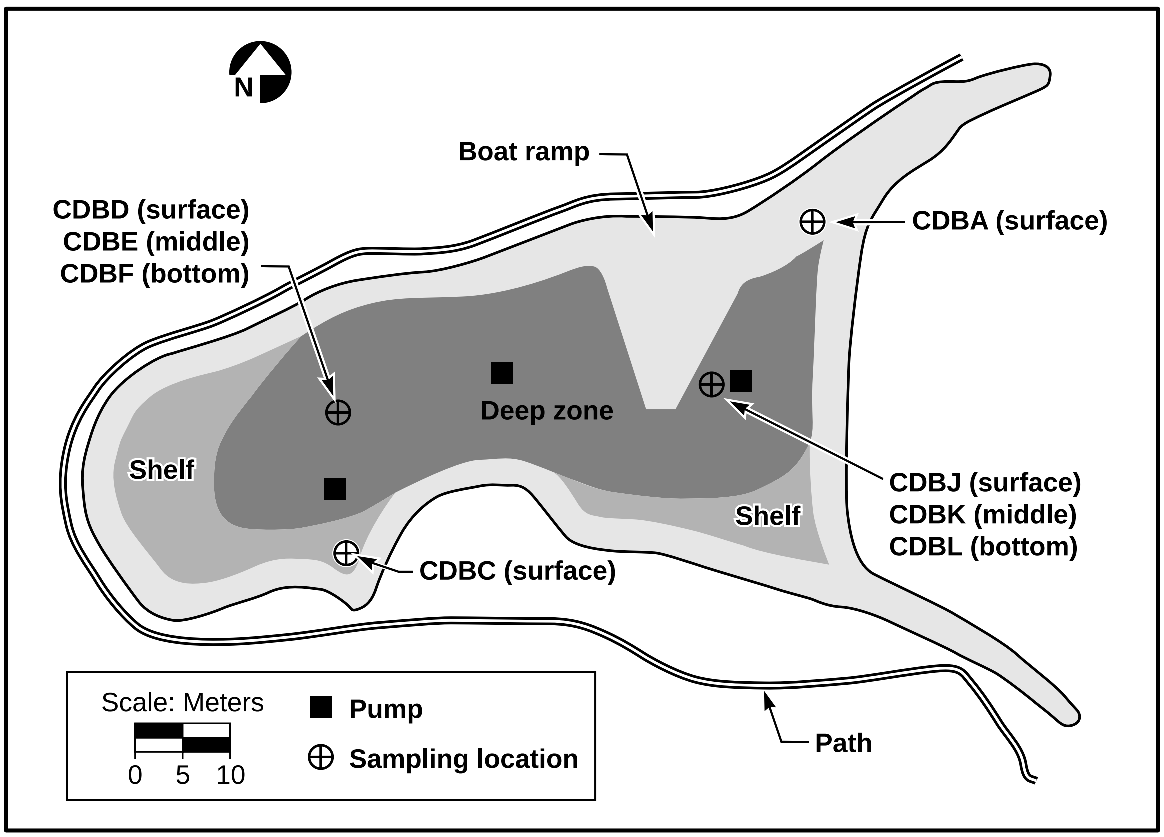

Figure 7-9. Sampling locations within the Drainage Retention Basin, 1997.

Table 7-10. Routine water quality management levels for the Drainage Retention Basin.

Constituent	Location	Frequency	Management action levels	
			Dry season Apr 1–Nov 30	Wet season Dec 1–Mar 31
Physical				
Dissolved oxygen (mg/L)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<80% saturation and <5 mg/L	<80% saturation and <5 mg/L
Temperature (°C)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<15 and >26	<15 and >26
Total alkalinity (as $CaCO_3$) (mg/L)	CDBE	Monthly	<50	<50
Chlorophyll-a (mg/L)	CDBE	Monthly	>10	>10
pH (pH units)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<6.0 and >9.0	<6.0 and >9.0
Total dissolved solids (mg/L)	CDBE	Monthly	>360	>360
Turbidity (m)	CDBE	Monthly	<0.91	<0.914
Chemical oxygen demand (mg/L)	CDBE	Quarterly	>20	>20
Oil and grease (mg/L)	CDBE	Quarterly	>15	>15
Conductivity (μmho/cm)	CDBE	Monthly	>900	>900
Nutrients (mg/L)				
Nitrate (as N)	CDBE	Monthly	>0.2	>0.2
Nitrite (as N)	CDBE	Monthly	>0.2	>0.2
Ammonia nitrogen	CDBE	Monthly	>0.1	>0.1
Phosphate (as P)	CDBE	Monthly	>0.02	>0.02
Microbiological (MPN[a]/0.1L)				
Total coliform	CDBE	Quarterly	>5000	>5000
Fecal coliform	CDBE	Quarterly	>400	>400
Metals (μg/L)				
Antimony	CDBE	Monthly	>6	not applicable
Arsenic	CDBE	Monthly	>50	>10
Beryllium	CDBE	Monthly	>4	not applicable
Boron	CDBE	Monthly	>7000	>7000
Cadmium	CDBE	Monthly	>5	>2.2
Chromium, total	CDBE	Monthly	>50	not applicable
Chromium(VI)	CDBE	Monthly	not applicable	>22

Table 7-10. Routine water quality management action levels for the Drainage Retention Basin (concluded).

Constituent	Location	Frequency	Management action levels	
			Dry season Apr 1–Nov 30	Wet season Dec 1–Mar 31
Copper	CDBE	Monthly	>1300	>23.6
Iron	CDBE	Monthly	not applicable	not applicable
Lead	CDBE	Monthly	>15	>6.4
Manganese	CDBE	Monthly	not applicable	not applicable
Mercury	CDBE	Monthly	>2	>2
Nickel	CDBE	Monthly	>100	>320
Selenium	CDBE	Monthly	>50	>10
Silver	CDBE	Monthly	>100	>8.2
Thallium	CDBE	Monthly	>2	not applicable
Zinc	CDBE	Monthly	not applicable	>220
Organics (μg/L)				
Total volatile organic compounds	CDBE	Semiannually	>5	>5
Benzene	CDBE	Semiannually	>0.7	>0.7
Tetrachloroethene	CDBE	Semiannually	>4	>4
Vinyl chloride	CDBE	Semiannually	>2	>2
Ethylene dibromide	CDBE	Semiannually	>0.02	>0.02
Total petroleum hydrocarbons	CDBE	Semiannually	>50	>50
Polynuclear aromatic hydrocarbons	CDBE	Semiannually	>15	>15
Base/neutral acid extractable compounds	CDBE	Semiannually	>5	>5
Pesticides and herbicides	CDBE	Quarterly	not applicable	not applicable
Radiological (Bq/L)				
Gross alpha	CDBE	Semiannually	>0.555	>0.555
Gross beta	CDBE	Semiannually	>1.85	>1.85
Tritium	CDBE	Semiannually	>740	>740
Toxicity (% survival/96-hour)				
Aquatic bioassay fathead minnow	CDBE	Annually	90% survival median, 90 percentile value of not less than 70% survival	90% survival median, 90 percentile value of not less than 70% survival
Chronic bioassay fathead minnow	CDBE	Annually	not applicable	not applicable
Chronic bioassay selanastrum	CDBE	Annually	not applicable	not applicable

[a] Most probable number.

Samples collected during 1997 within the DRB at CDBE did not meet the management action levels (MALs) for dissolved oxygen, temperature, turbidity, nitrate, ammonia, and phosphorus (**Table 7-11**). No action was taken to adjust nutrient levels. Operating the pumps to increase the DO level resulted in increased turbidity. No action was taken in response to the temperature changes since the low temperatures were consistent with normal seasonal patterns.

Table 7-11. Summary of Drainage Retention Basin monitoring at sampling location CDBE exceeding management action levels.

Constituent	Management action levels	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dissolved oxygen (mg/L), monthly average	<80% saturation and >5 mg/L	—	73%	68%	—	—	50% 4.4	75%	—	—	56%	34%	38% 4.5
Temperature (°C), monthly average	<15.6 >26.7	8.8	11.6	14.1	14.2	—	—	—	—	—	—	—	8
Turbidity (Secchi disk) (m), monthly average	<0.914	0.203	0.381	0.499	0.590	0.804	—	0.491	0.711	0.677	0.372	0.679	0.457
Nitrate (as N) (mg/L)	≥0.2	0.5	0.5	0.5	0.4	—	—	0.4	—	—	0.29	0.72	0.56
Ammonia nitrogen (mg/L)	>0.1	—	0.12	—	—	—	—	—	—	—	0.44	—	0.26
Phosphate (as P) (mg/L)	≥0.02	0.66	0.57	0.64	0.54	0.46	0.37	0.32	0.31	0.49	0.24	0.21	0.20
Total dissolved solids (mg/L)	>350	—	—	—	—	—	—	—	—	414	440	463	355
Chemical oxygen demand (mg/L)	>20	52.2	—	—	32.2	—	—	34	—	—	27	—	—
Fecal coliform (MPN/100mL)	>500	>1600	—	—	—	—	—	—	—	—	—	—	—

DO concentrations varied around the MAL of at least 80% saturation of oxygen in the water for most of the year and dropped below the MAL of 5 mg/L several times during 1997 (**Figure 7-10**). During the late summer through the end of the year, the primary DO meter that LLNL uses began providing questionable data. Careful meter calibration initially resulted in more realistic results. However, comparative testing using back-up

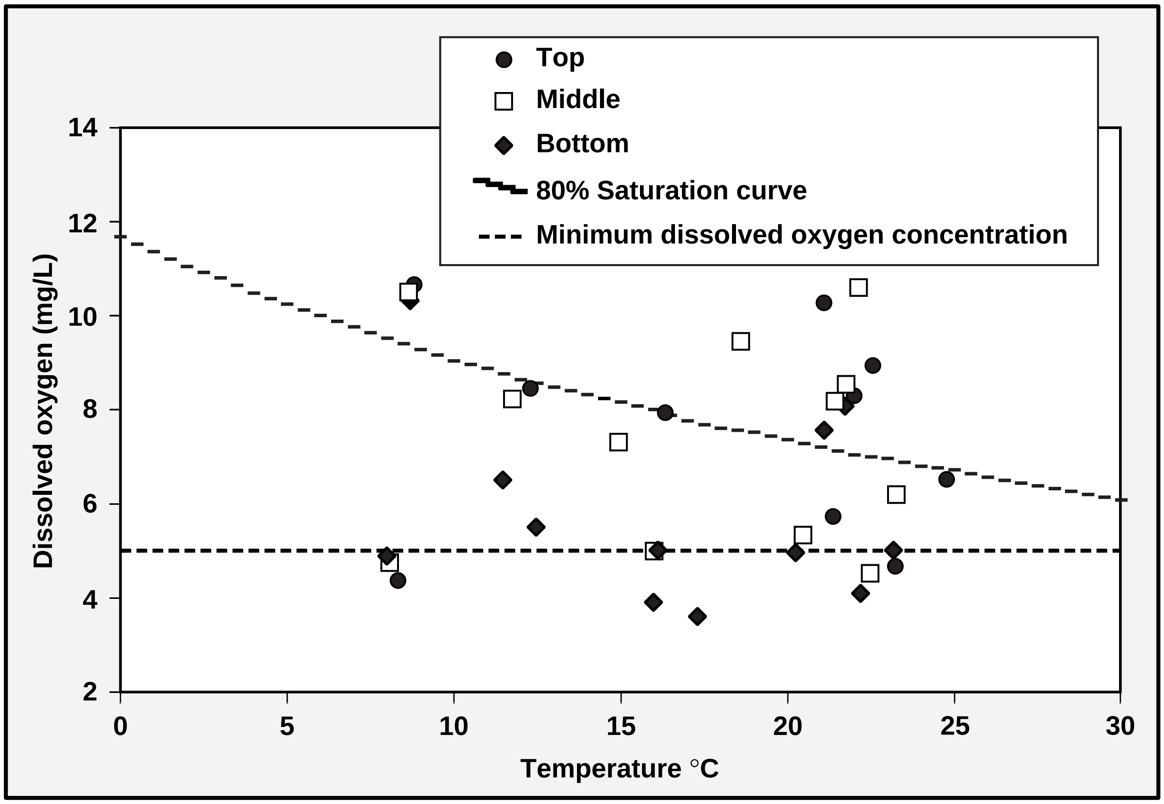

Figure 7-10. Monthly average dissolved oxygen vs. temperature at each depth location in the Drainage Retention Basin from January through December 1997.

meters and wet chemistry methods to measure the dissolved oxygen indicated that the meter was providing readings as much as 2 mg/L below the comparison values. So the majority of the dissolved oxygen readings collected from June through December are probably not accurate. The meter was replaced with a new one in 1998.

Dissolved oxygen concentrations are controlled manually with aeration pumps, which are started whenever oxygen concentrations at any level of the DRB drop close to or below the critical MAL of 5 mg/L. In 1997, these pumps were operated continuously from June through December. During the winter, the pumps were started as needed.

Pump operation was probably responsible for the relatively uniform distribution of dissolved oxygen at the surface, middle, and bottom elevations seen throughout the five years of DRB operation. Adequate DO concentrations prevent decaying organic matter in bottom sediments from releasing nutrients into the DRB water column. When the pumps were not operated in 1997 until June, oxygen concentrations began to drop in the lower level of the DRB (**Figure 7-11**). Temperature, the other important parameter in determining how much oxygen is dissolved in water, showed characteristic seasonal

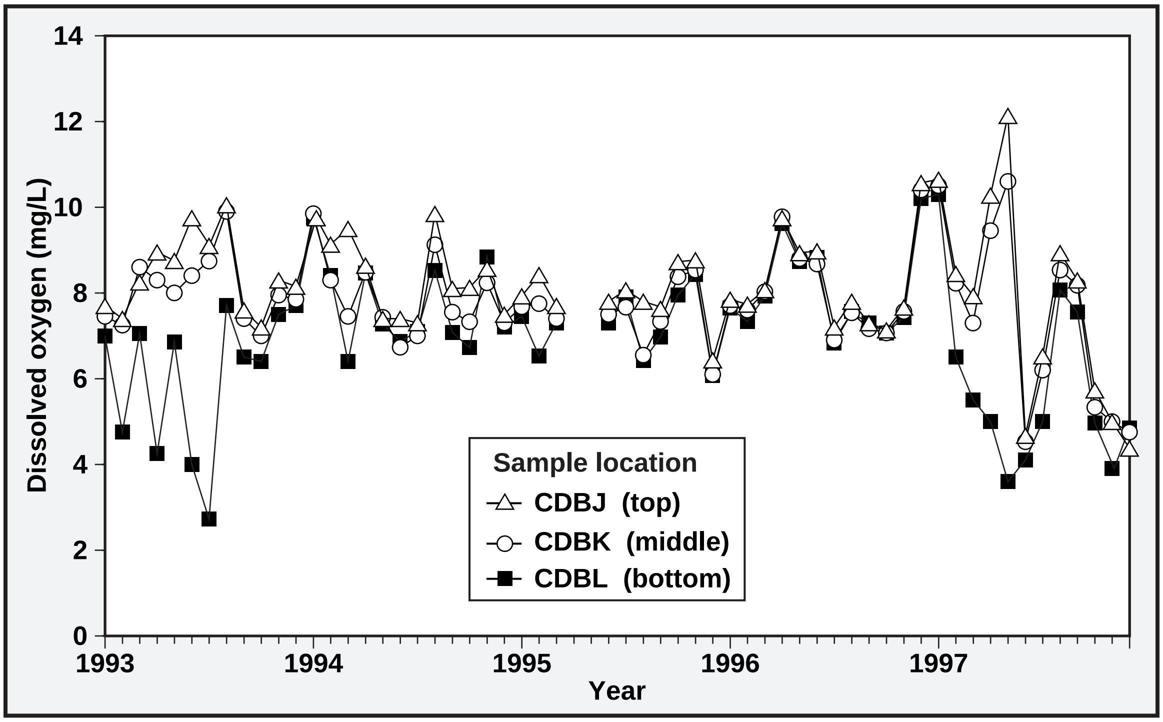

Figure 7-11. Dissolved oxygen concentration variations from the beginning of DRB operations.

trends (**Figure 7-12**). The uniform distribution of temperature in the top, middle, and bottom elevations reflects the uniform mixing achieved by the operation of the pumps. This uniform mixing provides further evidence that the low dissolved oxygen readings seen in the last half of 1997 were not accurate.

Turbidity rose above acceptable management levels during the 1993/1994 wet season, and remained above them throughout 1994 and 1995. Wet season turbidity probably results from sediments that pass through the sediment traps discharging into the DRB. Turbidity seen during the warmer summer months of 1994 was most likely the result of algae growth (Harrach et al. 1996). This was confirmed by high chlorophyll-a values and visual observations during the 1994 summer months. However, during 1995, though turbidity continued to be high, chlorophyll-a values were just above detection, indicating very little algae growth. This was confirmed by visual observations. The inhibition of algae growth continued through 1996. In 1997, the DRB again began showing higher chlorophyll-a levels and visible algae growth.

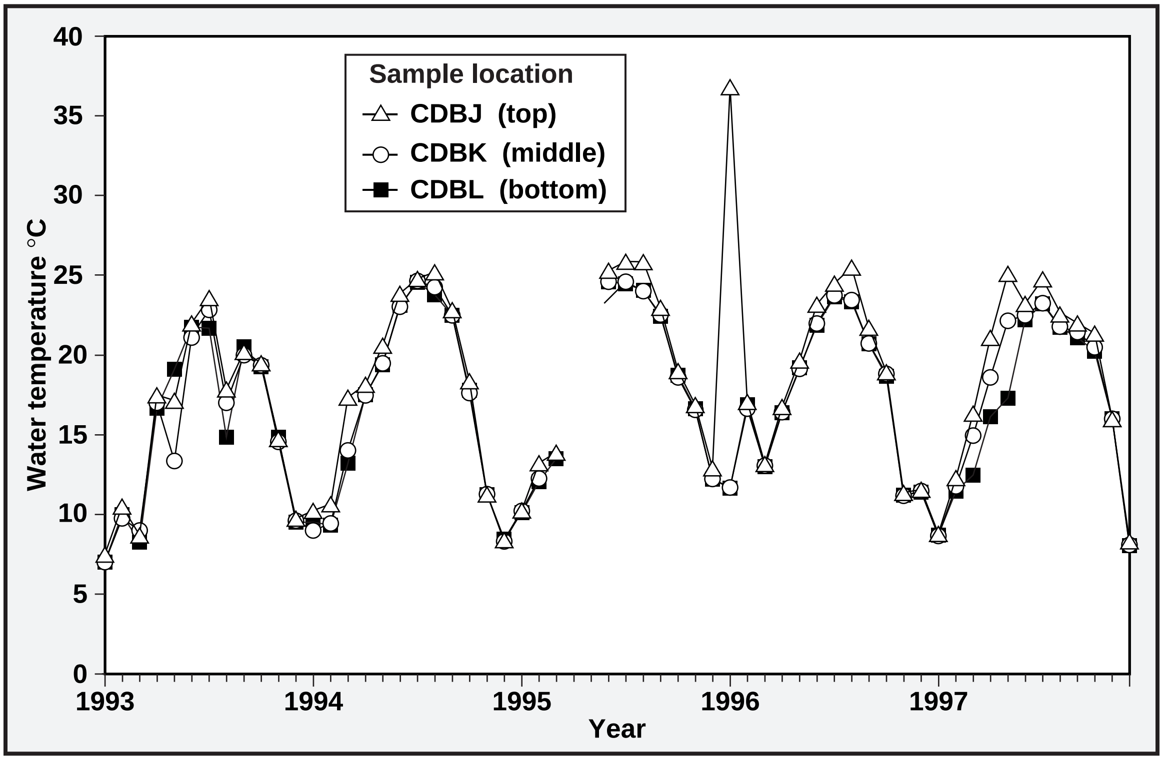

Figure 7-12. Seasonal temperature variation measured at sample top, middle, and bottom levels from the start of operation in 1993. No measurements are available for April and May 1995.

During 1996/1997, LLNL began conducting studies to explain decreased algae growth observed during 1995 and 1996. LLNL did additional toxicity monitoring and some informal toxicity reduction evaluation studies using the algae *Selanastrum capricornum*. The studies looked for negative effects on the algae growth when metals were present in water collected from the DRB and when organic compounds were present. Reduced algae growth rates were observed in the collected water samples containing organic compounds. Further studies to confirm which organic compounds might be impacting algae growth in the DRB looked at the algae growth response to tan bark extract and two herbicides, diuron and bromacil. These studies showed statistically significant differences (p=0.0001) between the control and water containing extract from the tan bark spread near the DRB and water containing the active ingredients of the two herbicides. Diuron and bromacil are used commonly around the Livermore site to control weeds growing in the drainage channels. However, samples containing these pesticides showed greater toxic effects than samples containing the tan bark extract. Toxic effects on the algae were evident when these herbicides were found in water samples collected from the DRB in October 1995 and September 1997.

In 1997, diuron was introduced into the DRB due to a misapplication of this pesticide. Toxicity testing after the influx of this material showed a toxic effect of greater than 20 toxicity units in DRB water containing a diuron concentration of 33 µg/L. Diuron continued to be seen in the DRB, discharges into the DRB, and in discharges at WPDC through the end of the year. Concentrations ranged approximately from 18 µg/L to 40 µg/L.

LLNL began monitoring the flow discharging from the DRB in 1996 (for 1997 flow, see **Figure 7-13**). Storm water runoff accounts for the majority of the water entering the DRB. Discharges normally occur only in the wet season, and are usually associated with storms. However, in 1997 one manual discharge occurred during the dry season when additional discharges from Treatment Facility F were routed to the DRB to prevent discharges into the storm drainage system while the construction of the National Ignition Facility temporarily made the downstream storm drain inaccessible. A total of 142 ML (37.6 million gal) of water was discharged from the DRB in the months of January, February, September, November, and December. The largest discharge occurred on January 1, 2, and 22, when 40 ML (10.6 million gal) were released. This accounted for 28% of the total annual discharge.

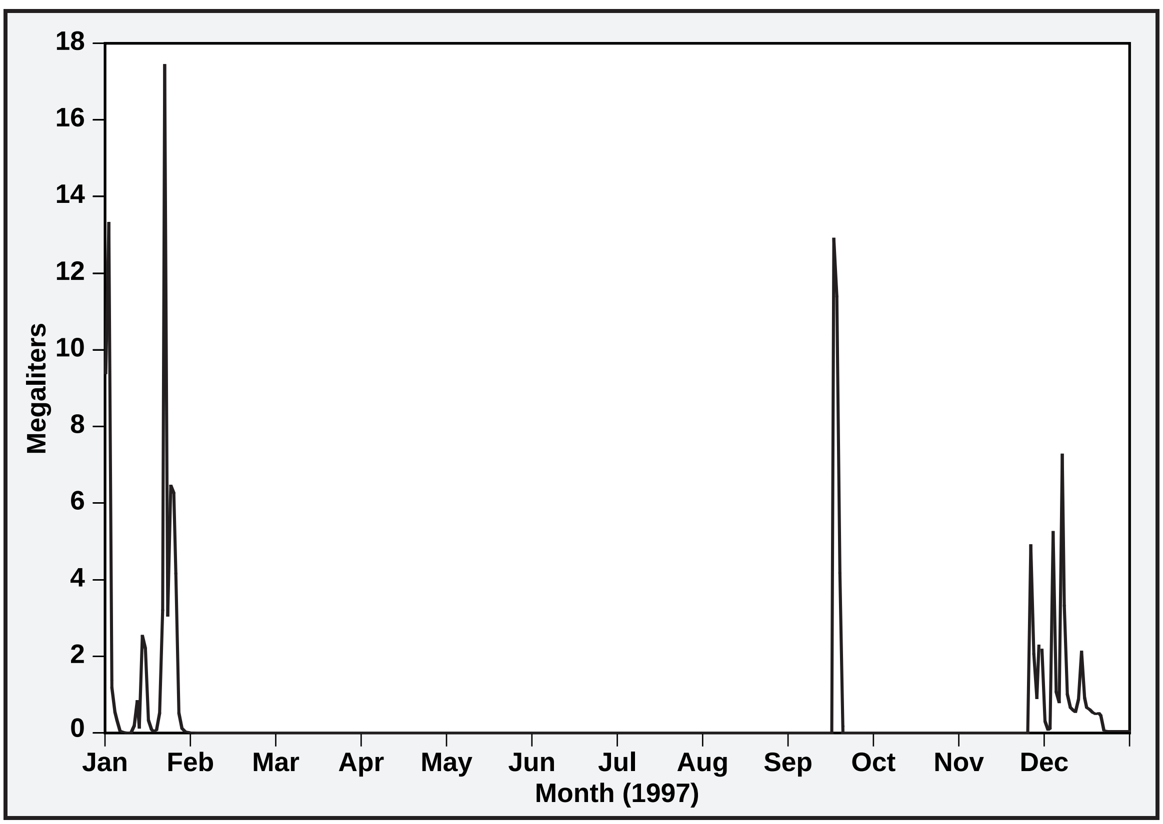

Figure 7-13. Water discharged from the Drainage Retention Basin in 1997.

Nevertheless, mass loadings for discharges from the DRB, determined from flow and analytical data, show that the total measurable mass of metals and organics released from the DRB is small (see Table 7-6 of the Data Supplement).

Data for maintenance monitoring at sampling locations CDBX, WPDC, CDBA, CDBC, CDBD, CDBE, CDBF, CDBJ, CDBK, and CDBL are presented in Tables 7-6, 7-7a, b, and c, 7-8, and 7-9 in the Data Supplement.

Treatment Facilities

The Livermore Site Ground Water Project (GWP) complies with provisions specified in a federal facility agreement (FFA) and in the CERCLA ROD entered into by the Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (RWQCB). As required by the FFA, the project addresses compliance issues through investigations of potential contamination source areas (such as suspected old release sites, solvent handling areas, and leaking underground tank systems), continued monitoring of ground water, and remediation. The ground water constituents of concern are volatile organic compounds (VOCs), primarily trichloroethene (TCE) and tetrachloroethene (or perchloroethylene [PCE]). The primary treatment technology employed at the LLNL Livermore site to remediate contaminated ground water is ground water pump-and-treat. This technology employs a dense network of ground water extraction wells, monitoring wells, pipelines, and surface treatment facilities.

At Site 300, ongoing remedial investigations, feasibility studies, engineering evaluation and cost analyses, and remedial actions are being performed by the Environmental Restoration Program and Division. Site 300 investigations and remedial actions are conducted under the combined oversight of the EPA, Central Valley RWQCB, and DTSC, and under the authority of an FFA for the site. (There are separate agreements for Site 300 and the Livermore site.) Pump-and-treat technology is utilized for ground water treatment.

Livermore Site

Livermore site treatment facilities that discharge to surface water drainage courses (**Figure 7-14**) are discussed in this section.

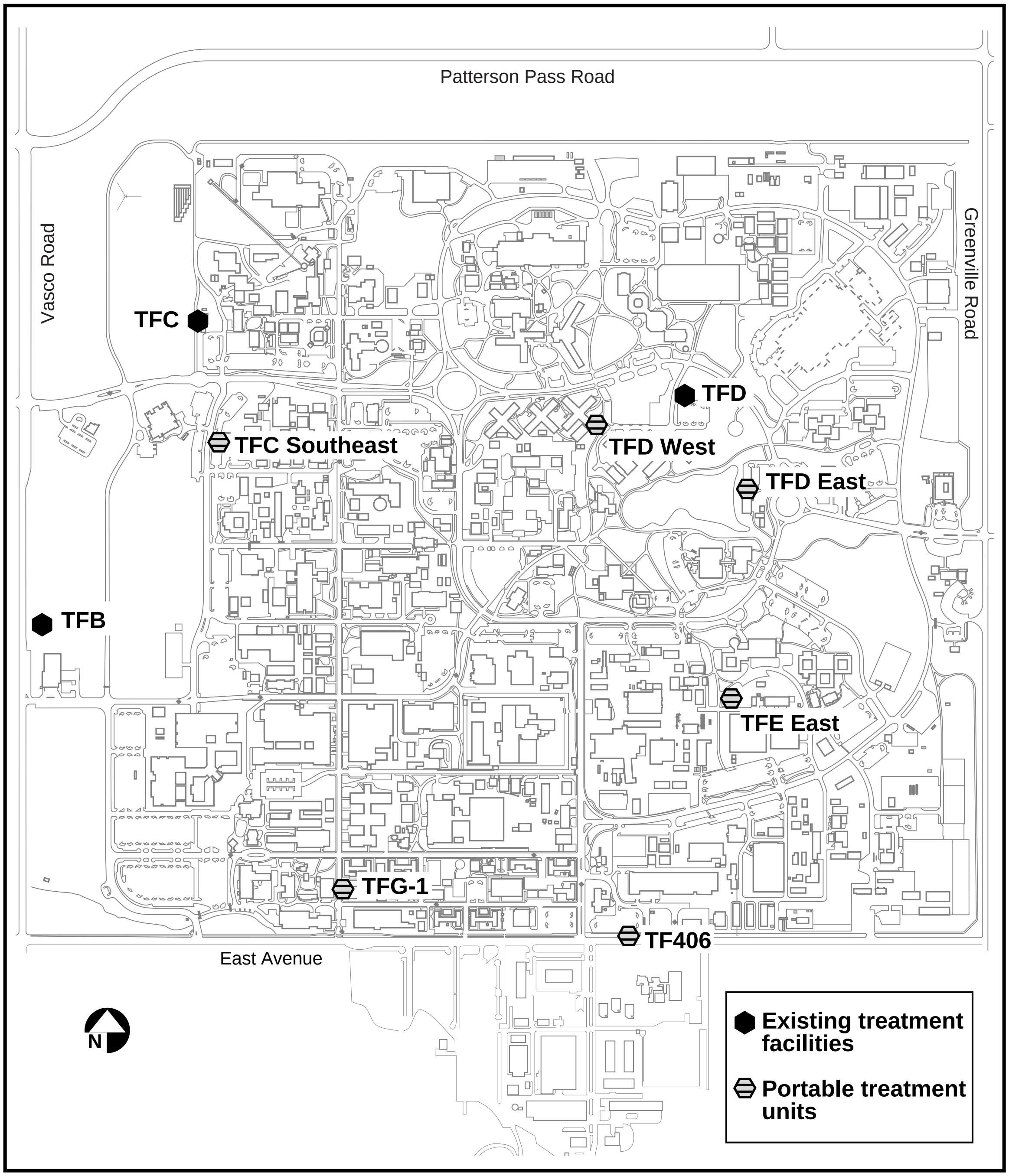

Figure 7-14. Location of treatment facilities that discharge to surface water drainage courses.

Treatment Facility B (TFB). Treatment Facility B (TFB), located along Vasco Road just north of Mesquite Way, processes ground water contaminated with chromium and VOCs. A combination of UV / H_2O_2 treatment and air-stripping technologies is used to treat VOCs. Hydrogen peroxide and carbon dioxide are used to reduce chromium(VI) to chromium(III). TFB's treated waters are discharged into a drainage ditch at the west perimeter of the site that feeds Arroyo Las Positas. TFB treated about 64 ML of ground water in 1997, removing and destroying approximately 6.8 kg of VOCs. Between system startup in 1990 and 1997, TFB processed 247 ML of ground water and removed about 25.5 kg of VOCs from the subsurface.

Self-monitoring analytical results of TFB effluent samples indicate that the VOC discharge limit of 5 ppb was not exceeded. During 1997, water discharged from TFB did not contain chromium(VI) in excess of the discharge limit of 22 ppb (µg / L) in accordance with the CERCLA ROD as amended (**Table 7-9**).

Treatment Facility C (TFC) and TFC Southeast. Treatment Facility C (TFC) is located in the northwest quadrant of LLNL and uses air-stripping and ion-exchange technologies to process ground water contaminated with VOCs and chromium. TFC includes a PTU, TFC Southeast. In 1997, a total of 9.4 kg of VOCs was removed from approximately 86 ML of ground water treated at TFC. Between system startup in October 1993 and 1997, TFC processed about 135 ML of ground water and removed about 15.4 kg of VOCs. The treated water from TFC is discharged into Arroyo Las Positas.

LLNL conducted samplings at TFC in compliance with the modified CERCLA ROD discharge limits (**Table 7-9**). The self-monitoring analytical results of TFC effluent samples indicate that the VOC discharge limit of 5 ppb was not exceeded during 1997. All regulated metals parameters were below discharge limits designated in the CERCLA ROD as amended.

Treatment Facility D. Treatment Facility D (TFD) is located in the northeast quadrant of LLNL and uses air-stripping and ion-exchange technologies to process contaminated ground water. TFD was activated on July 14, 1994, and began operating on September 15, 1994. Two additional extraction locations, TFD West (TFD-W) and TFD East (TFD-E) were activated in 1997 using portable treatment units (PTUs). Since startup, the combined TFD facilities have processed nearly 229 ML of ground water and removed about 73.4 kg of VOC mass from the subsurface. In 1997, the combined TFD facilities processed about 182 ML of ground water containing about 55 kg of VOCs. The treated water was discharged through storm water drainage channels into Arroyo Las Positas.

LLNL sampled TFD effluent in compliance with the modified CERCLA ROD. The self-monitoring analytical results indicated that metals and VOCs were within compliance discharge limits during 1997.

Treatment Facility E. Multiple PTUs will be located in the Treatment Facility East (TFE) area in the southeastern quadrant of the LLNL Livermore site. In 1997, one PTU, TFE East (TFE-E), was operating in the area. TFE-E is located west of Avenue H near Third Street in the east-central portion of the site (**Figure 7-14**). TFE-E treats ground water from extraction Well W-1109 (Hydrostatic Unit [HSU] 2) and extraction Well W-566 (HSU 5). TFE-E was operated at flow rates ranging from 15 to 20 gpm in 1997.

TFE-E processes ground water for treatment of VOCs using an air stripper. The effluent air is treated using granulated activated carbon (GAC) to remove VOCs prior to discharge to the atmosphere. Treated ground water from TFE-E is discharged into a drainage ditch flowing north into the DRB.

Since it was activated on November 26, 1996, TFE-E PTU has processed approximately 37.5 ML of ground water through the end of 1997, and removed an estimated 16.7 kg of VOC mass from the subsurface. In 1997, this facility processed approximately 36 ML of ground water and removed an estimated 15.9 kg of VOCs. Water treated at TFE East is discharged to a north-flowing drainage ditch that ultimately empties into the Drainage Retention Basin. TFE-E was in compliance with all permits throughout 1997.

Treatment Facility 406 (TF406). Located in the southeastern part of the LLNL Livermore site (**Figure 7-14**), TF406 consists of a PTU that uses air stripping to treat ground water. TF406 is designed to treat VOCs extracted from HSUs 4 and 5 beneath the former TFF area.

TF406 began operating on August 27, 1996. TF406 processes ground water extracted from Well W-1114, which is positioned to clean up and hydraulically control a TCE plume. In the spring of 1997, TF406 also began treating ground water from Well GSW-445.

During 1997, TF406 processed about 8.7 ML of ground water from Well W-1114 and Well GSW-445 at flow rates between 38 and 60 L/min. The total VOC mass removed during 1997 was about 0.9 kg. Since startup, TF406 has treated 10.2 ML of ground water and removed about 1.1 kg of VOCs. All treated ground water was discharged to a storm drain that leads to Arroyo Las Positas. There were no compliance violations associated with this discharge during 1997.

Treatment Facility G (TFG-1). Treatment Facility G-1 (TFG-1) is located about 90 m (300 ft) north of East Avenue in the south-central part of the LLNL Livermore site (**Figure 7-14**). TFG-1 consists of a PTU that utilizes air stripping and ion exchange to treat ground water from HSU 2 extraction Well W-1111.

During 1997, TFG-1 processed about 12.5 ML of ground water and removed 6.6 kg of VOCs. TFG-1 has removed an estimated 0.8 kg of VOCs from 16.3 ML of ground water since operation began on April 11, 1996. All treated ground water was discharged to a storm drain located about 15 m north of TFG-1, which empties into Arroyo Seco. There were no compliance violations associated with this discharge during 1997.

Site 300

Site 300 treatment facilities that discharge to surface drainage courses are discussed in this section. They are the Central General Services Area Treatment Facility and the Eastern General Services Area Treatment Facility (see **Figure 7-6**).

General Services Area

The central GSA ground water treatment system is operating under substantive requirements for wastewater discharge issued by the Central Valley RWQCB. The central GSA treatment facility discharges to bedrock in the eastern GSA canyon, where the water percolates into the ground. The eastern GSA ground water treatment system operates under NPDES Permit No. CA0082651, issued by the Central Valley RWQCB for discharges into Corral Hollow Creek. The system operated under WDR91-052 until December 5, 1997, when WDR 97-242 was issued. Permit requirements for the central and eastern GSA ground water treatment system are listed in **Table 7-12**. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 1997. The GSA operable unit is located in the southeastern corner of Site 300.

Since 1982, LLNL has conducted an intensive investigation in the GSA and off-site areas to locate VOC release points and to define the vertical and horizontal distribution of VOCs, primarily TCE and PCE, in the soil, rock, and ground water. According to the *Final Site-Wide Remedial Investigation* (Webster-Scholten 1994) and *Draft Remedial Investigation* (McIlvride et al. 1990) reports, VOCs in excess of drinking water MCLs have been identified in the shallow ground water beneath the GSA in two localities. Two small VOC plumes occur in the central GSA portion of the operable unit, and one VOC plume occurs in the eastern GSA section in the gravels of Corral Hollow Creek.

Table 7-12. General Services Area ground water treatment system surface discharge permit requirements.

Parameter	Treatment facility	
	Central General Services Area	**Eastern General Services Area**
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.
Temperature	No alteration of ambient receiving water conditions more than 3°C.	No alteration of ambient receiving water conditions more than 3°C.
Place of discharge	To ground water during dry weather and to surface water drainage course in eastern GSA canyon during wet weather.	Corral Hollow Creek.
Flow rate	272,500 L (30-day average daily dry weather maximum discharge limit).	272,500 L per day
Mineralization	Mineralization must be controlled to no more than a reasonable increment.	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 µg/L. EPA Method 602—method detection limit of 0.3 µg/L.	EPA Method 601—detection limit of 0.5 µg/L.

Eastern GSA

The air-sparging ground water treatment unit, which began operation in June 1991 as a CERCLA Removal Action to remove VOCs from the eastern GSA ground water, was replaced in January 1997 by several aqueous-phase granular activated carbon (GAC) adsorption units. The GAC units were demonstrated to be effective in removing VOCs from ground water, less complex in both design and operation than air-sparging technology, and less expensive than the sparging tanks.

During 1997, 80.8 ML of ground water containing 0.35 kg of VOCs were removed and treated at the Eastern GSA ground water treatment system. The treated ground water was discharged off site to the Corral Hollow Creek, in accordance with NPDES Permit No. CA0082651.

Since cleanup was initiated, approximately 5 kg of VOCs have been removed from 410 ML of water, and the length of the eastern GSA TCE plume with concentrations over the cleanup standard of 5 ppb maximum contaminant level (MCL) has been reduced by over 1432 m (4700 ft). The off-site portion of the plume now extends only 30.5 m (100 ft) beyond the site boundary. TCE concentrations in influent from the Eastern GSA ground water treatment system were reduced from 64 ppb in January 1992 to below MCLs (5 ppb) in September 1997. During this same time, VOC concentrations in eastern GSA monitoring well samples were reduced by up to 84%. The number of off-site wells in the Eastern GSA with TCE concentrations over the cleanup standard of 5 ppb (MCL) was reduced from five wells to only one. LLNL estimates that eight more years of ground water extraction and treatment will be required to achieve and maintain ground water VOC concentrations below MCLs at the Eastern GSA.

Central GSA

The two VOC ground water plumes in the central GSA are present in alluvium and shallow bedrock and in deeper bedrock. Construction of an air-sparging ground water treatment system and a vapor extraction and treatment unit for a CERCLA Removal Action to remove VOCs from the central GSA ground water and soil vapor was completed in 1993. During 1993, ground water extraction and treatment began. In August 1997, the air-sparging treatment tanks were replaced with air strippers in a portable treatment unit (PTU). The PTU is more cost-effective than the sparging tanks; may be easily deployed to another Site 300 operating unit if a more innovative and effective technology is identified for use at the central GSA in the future; and reduces costs originally projected in the GSA Feasibility Study document.

From 1993 through the end of 1997, about 3.2 ML of ground water containing 5.6 kg of VOCs were treated. The treated ground water was collected and batch-discharged in a remote Site 300 canyon, in accordance with the Substantive Requirement for wastewater discharge. During 1997, 0.7 ML of ground water containing 0.73 kg of VOCs was removed and treated at the Central GSA ground water treatment system (GWTS). TCE concentrations in Central GSA GWTS influent were reduced from 9400 ppb in April 1993 to 380 ppb in October 1997.

Following dewatering of bedrock through ground water extraction, soil vapor extraction and treatment of VOCs began in 1994. From 1994 through the end of 1997, soil vapor was treated with carbon adsorption to remove 30.3 kg of VOCs. During 1997, 47,438 cubic meters of soil vapor were extracted and treated at the Central GSA soil vapor extraction (SVE) system to remove 0.72 kg of VOCs. VOC concentrations in the Central GSA SVE influent stream were reduced from 450 parts per million volume-per-volume ($ppm_{v/v}$) to below 5 $ppm_{v/v}$. VOC concentrations in individual Central GSA SVE wells have been significantly reduced.

Building 834 Complex

During the portion of the year that the GWTS was in full-scale operation, 90.8 ML of ground water were extracted and treated; 5.2 kg of VOCs and 133 g of organosilicate oil were removed. Of the VOCs, an average of 84% was TCE. The 834 GWTS is expected to resume operation in 1998.

Cooling Towers

LLNL samples cooling-tower wastewater discharges as required by the Self-Monitoring Program of WDR 94-131, NPDES Permit No. CA0081396, and reports the results of the compliance sampling to the Central Valley RWQCB quarterly.

The cooling towers, used to cool buildings and equipment at Site 300, discharge noncontact cooling water to man-made and natural drainage courses (**Figure 7-15**). These drainage courses flow into Corral Hollow Creek, a tributary of the San Joaquin River.

WDR 94-131 establishes effluent limits for three parameters: (1) Daily flow must not exceed the maximum design flow; (2) Total dissolved solids (TDS) must not exceed a monthly average of 2000 mg/L or a maximum daily limitation of 2400 mg/L; and (3) The pH must not exceed 10. Along with effluent monitoring, when Corral Hollow Creek is flowing, the permit requires LLNL to collect pH samples upstream and downstream of the cooling tower discharge points into the creek and to conduct visual observations of the creek. (On July 1, 1997, the upstream sampling location was changed from NSTN to CARW [**Figure 7-15**] to provide better sampling access.) Cooling tower discharges must not raise the pH of Corral Hollow Creek above 8.5 or alter the ambient pH by more than 0.5 unit.

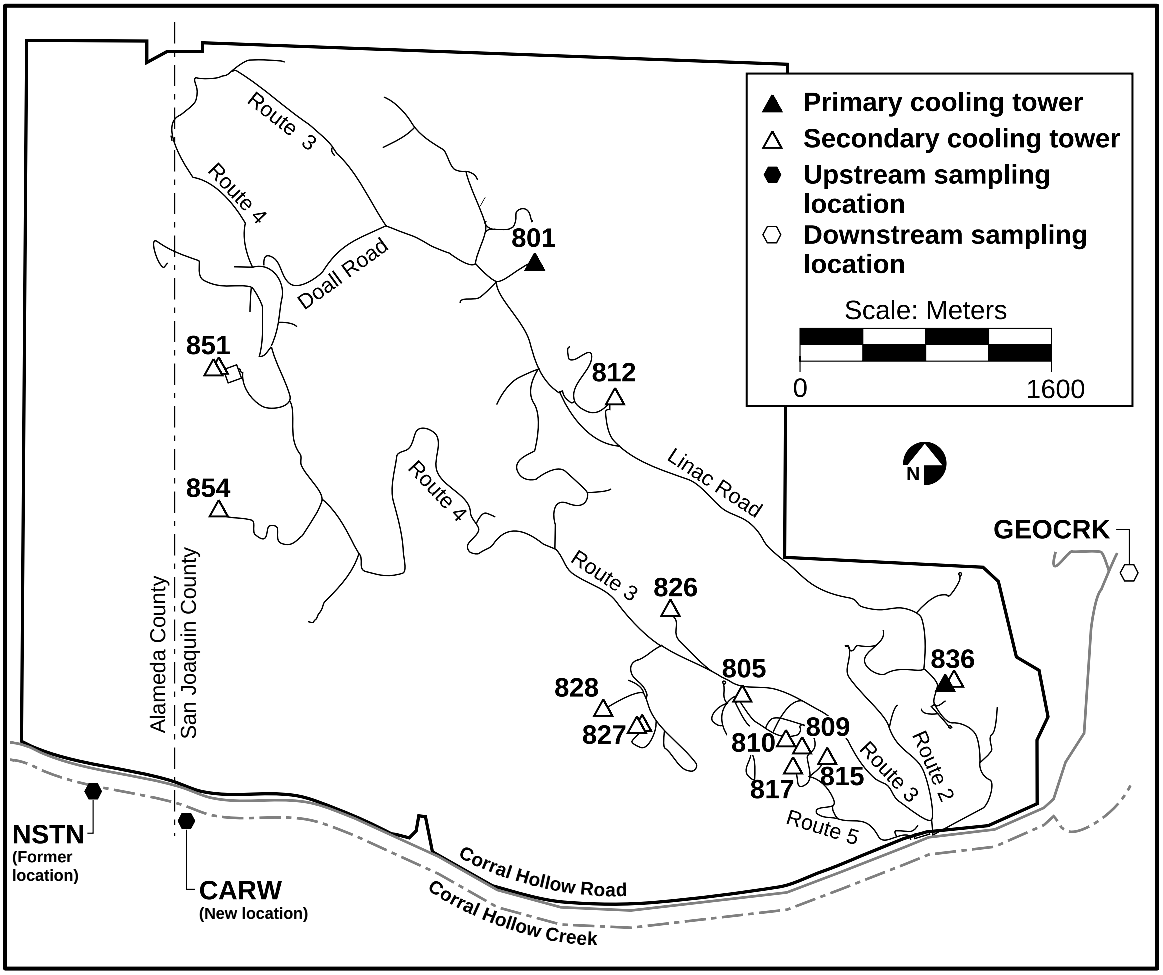

Figure 7-15. Site 300 cooling tower locations, 1997.

Two cooling towers, located at Buildings 801 and 836A, regularly discharge to surface water drainage courses. Fourteen other cooling towers routinely discharge to percolation pits under a waiver of waste discharge requirements from the Central Valley RWQCB. The permit establishes separate effluent limits (dissolved solids must not exceed a monthly average of 2000 mg/L or 5000 mg/L daily; pH must not exceed 10) for these 14 towers in the event that discharge to surface water drainage courses is necessary, such as during maintenance of the percolation pits. One such discharge occurred in August of 1997 when flow from the Building 812 cooling tower was diverted to the storm water drainage course for repair of a plugged line between the cooling tower and the percolation pit. Flow returned to the percolation pit by October 1997. Quarterly sampling (third quarter: 900 mg/L TDS, 8.9 pH; fourth quarter: 700 mg/L TDS, 8.57 pH) demonstrated compliance with the permitted limits. Although no compliance flow measurements were taken, maintenance mechanics' operational flow measurements demonstrated compliance.

The cooling towers at Building 851 were upgraded in March of 1997, and came back on line in mid-April 1997. This upgrade included replacing the chlorine biocide with an iodine biocide. The Central Valley RWQCB approved use of the new treatment chemical. Although these towers normally discharge to a percolation pit, occasional discharge to surface water drainages may occur. LLNL sampled the discharge and conducted a 96-hour fish toxicity study, using fathead minnow, which resulted in 100% survival. In addition to the toxicity study, LLNL analyzed samples for a variety of other constituents for comparison with cooling tower data in Attachment D of WDR 94-131. These analytes either do not have any identified water quality goals, or the results were well below water quality goals identified in the Central Valley RWQCB's staff report, *A Compilation of Water Quality Goals* (Marshack 1995). The analysis results were consistent with the cooling tower data noted in Attachment D of WDR 94-131, and were reported in the report to the Central Valley RWQCB for the second quarter of 1997.

In April 1997, residual water in the basin of the cooling tower at Building 865 was discharged to the surface water drainage course during the decommissioning process. Samples of the residual water taken prior to the discharge demonstrated compliance with permit limits (1600 mg/L TDS, 8.87 pH).

Monitoring results demonstrate that all cooling tower discharges were in compliance with all permitted limits (see **Tables 7-13** and **7-14**). LLNL reports operational values at the request of the CVRWQCB, but they are not used to determine compliance. All pH samples collected from the cooling tower discharges were below the permitted maximum of 10. TDS concentrations are consistently below both the daily maximum and monthly average limits. During the 1997 reporting period, flow occurred in Corral Hollow Creek during the first and second quarter. WDR 94-131 specifies that cooling tower discharges must not raise the pH of Corral Hollow Creek above 8.5 or alter the ambient pH by more than 0.5 unit. The first and second quarter downstream pH measurements (at location GEOCRK) of 8.42 and 8.47, respectively, were below the 8.5 pH requirement. Corresponding upstream pH measurements (at location CARW) of 8.36 and 8.58 for the first and second quarters, respectively, verify that the ambient pH did not change by more than 0.5 unit in either quarter.

Table 7-13. Summary data from compliance monitoring of Site 300 primary cooling towers, 1997.

Test	Tower no.	Minimum	Maximum	Median	Interquartile range	Number of samples
Total dissolved solids (mg/L)[a]	801	1300	1600	1400	—[e]	4
	836A	680	1400	1205	—[e]	4
Flow (L/day)	801[b]	0	12,756	4361	5954	24
	836A[c]	0	5760	1159	1756	24
pH (pH units)[d]	801	8.9	9.1	9.0	—[e]	4
	836A	7.7	9.0	8.9	—[e]	4

a Maximum permitted total dissolved solids = 2400 mg/L.

b Maximum permitted design flow = 16,276 L/day.

c Maximum permitted design flow = 8138 L/day.

d Maximum permitted pH = 10.

e Not enough data points to determine.

Table 7-14. Summary data from operational monitoring of Site 300 primary cooling towers, 1997.

Test	Tower no.	Minimum	Maximum	Median	Interquartile range	Number of samples
Total dissolved solids (mg/L)[a]	801	1000	1600	1400	150	26
	836A	1100	1500	1250	100	26
pH (pH units)[b]	801	8.7	9.1	9.0	0.1	26
	836A	8.6	9.1	8.8	0.3	26

a Maximum permitted total dissolved solids = 2400 mg/L.

b Maximum permitted pH = 10.

Other Waters

Additional surface water monitoring is driven by DOE Order 5400.1, General Environmental Protection Program, and DOE Order 5400.5, Radiation Protection of the Public and the Environment. Surface and drinking water near the LLNL Livermore site and in the Livermore Valley are sampled at locations shown in **Figure 7-16** according to procedures set out in Appendix A of the *Environmental Monitoring Plan* (Tate et al. 1995).

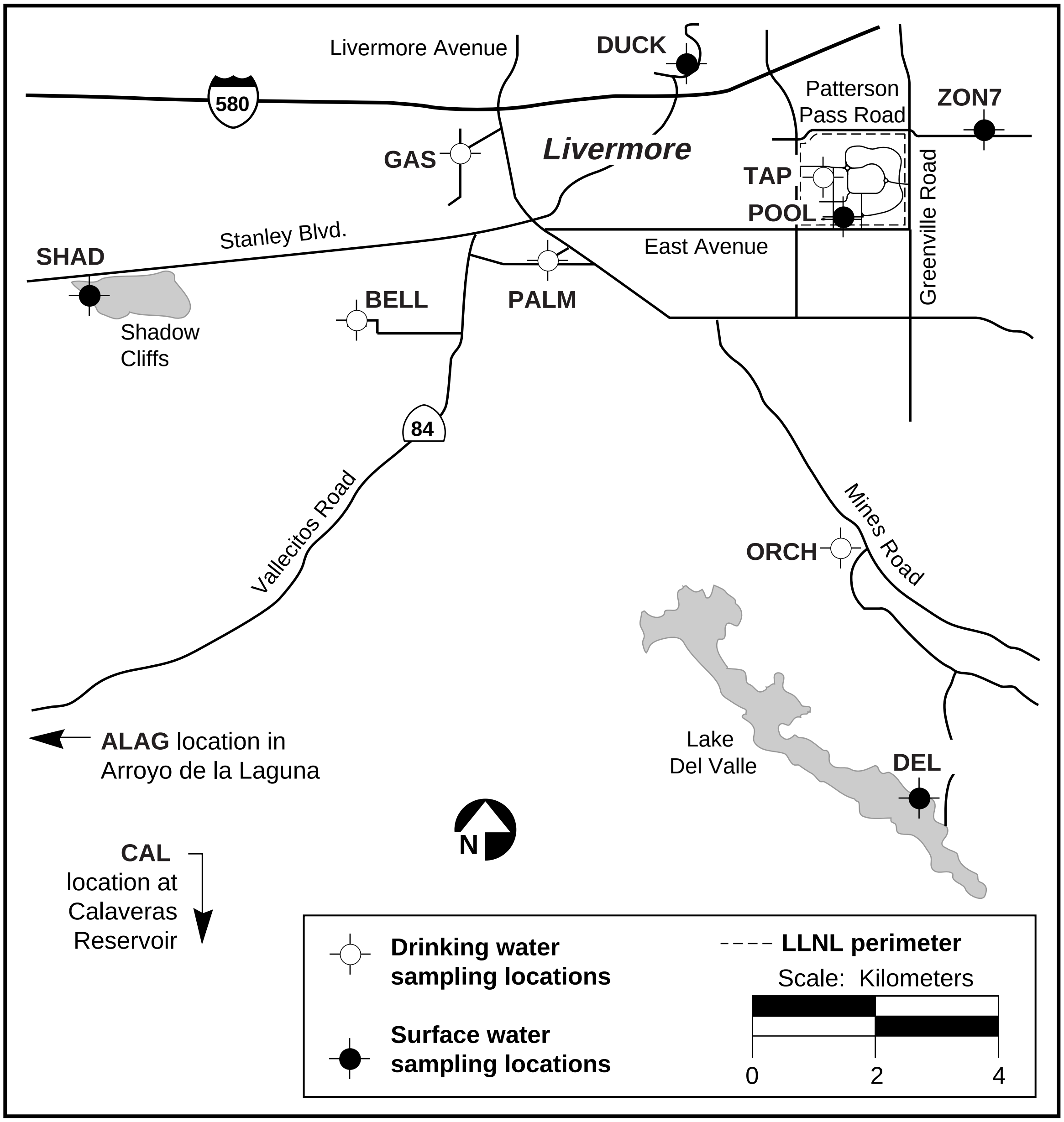

Figure 7-16. Surface and drinking water sampling locations, Livermore Valley, 1997.

Sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water sources; BELL, GAS, PALM, ORCH, and TAP are drinking water outlets. LLNL samples these locations for gross alpha, gross beta, and tritium. In the past, LLNL sampled these locations quarterly. Because past monitoring has consistently showed background levels of these constituents, samples were taken semiannually beginning in 1996. The on-site swimming pool POOL was also sampled, as described above, for gross alpha, gross beta, and tritium. POOL sampling frequency was reduced from monthly to quarterly beginning in mid-1997.

Median activity for tritium was less than 0.2% of the drinking water maximum contaminant level (MCL); the maximum tritium activity was less than 2% of the MCL. Median activities for gross alpha and gross beta radiation in surface water samples were less than 10% of the MCL. However, maximum activities detected for gross alpha and gross beta, respectively, were 0.29 Bq/L (7.94 pCi/L) and 0.40 Bq/L (10.8 pCi/L), or 52% and 22% of their respective MCLs (see **Table 7-15**). Detailed data are in Table 7-10 of the Data Supplement. Historically, gross alpha and gross beta radiation have fluctuated about the laboratory reporting limits. At these very low levels, the error measurements are nearly equal to the measured values so that no trends are apparent in the data.

Table 7-15. Radioactivity (in Bq/L) in surface and drinking water in the Livermore Valley, 1997.

	Tritium	Gross alpha	Gross beta
Median	1.33	0.051	0.14
Minimum	1.09	0.0025	0.016
Maximum	13.62	0.29	0.40
Interquartile range	1.27	0.040	0.10

Environmental Impacts

There is no evidence of adverse environmental impact resulting from releases from the Drainage Retention Basin. Although internal measurements indicated that concentrations were above the management action levels for several constituents, no water was discharged with constituents above amended limits. Although diuron was discharged at concentrations above where we have seen toxic effects within the DRB, these discharges occurred during periods of high storm water flows, and there was no evidence that these discharges impacted downstream receiving waters.

The environmental impact of tritium measured in rainfall samples from the Livermore site was negligible. The highest tritium activity measured in 1997 rainfall was 65 Bq/L, about 9% of the MCL for tritium (740 Bq/L). However, the median tritium level was much lower, at 3.9 Bq/L (see **Table 7-8**). The potential impact of tritium on drinking water supplies was estimated by determining the effective dose equivalent (EDE). Appendix B presents the method to calculate dose. The EDE to an adult who ingested two liters of water with 3.9 Bq/L tritium (the maximum rain concentration) per day for one year would be 0.0008 millisieverts (mSv), or 0.08 millirem (mrem), which is 0.08% of the DOE standard allowable dose of 1 mSv (100 mrem). Tritium activities measured in Livermore site and Livermore Valley surface and drinking water were even lower, with a maximum of 14 Bq/L, or about 2% of the MCL. The EDE to an adult who ingested two liters of this water per day for one year would be 0.0002 mSv (0.02 mrem), which is 0.02% of the DOE standard allowable annual dose of 1 mSv. Maximum activities for gross alpha and gross beta in Livermore site and Livermore Valley surface and drinking water were also below MCLs. The maximum activities for gross alpha and gross beta were 0.29 Bq/L and 0.40 Bq/L, or less than 11% of their respective MCLs (see **Table 7-15**). Maximum tritium activity in storm water (runoff) was 359 Bq/L, or 49% of the MCL (see **Table 7-4**). The EDE to an adult who ingested two liters of water at the maximum storm water tritium concentration for one year would be 0.0049 mSv (0.49 mrem), or 0.49% of the DOE standard allowable dose of 1 mSv. Tritium activities in subsequent samples were much lower, and the overall maximum, excepting the single high value of 359 Bq/L, was 21 Bq/L, or 3% of the MCL (see Table 7-1 of the Data Supplement). Drinking water at this level would result in an EDE of 0.0003 mSv (0.03 mrem), or 0.03% of the DOE standard allowable dose of 1 mSv. Maximum gross alpha and gross beta activities in storm water were 0.15 and 0.61 Bq/L, or 28% and 33% of their respective MCLs (see **Table 7-4**). Past studies, however, have indicated that the majority of the gross alpha and beta activities observed in runoff is due to naturally occurring radioisotopes carried by sediments in the runoff.

Concentrations of some metals in storm water seem to be increasing. Preliminary results indicate that these levels are related to suspended solids in the storm water. Further investigation into the source of these metals is planned. Samples collected during the 1997/1998 wet season for both dissolved and total metals will be evaluated to determine how much of the increase can be attributed to LLNL activities, to off-site sources, and to naturally occurring sediments. Although some 1997 storm water results were above criteria, there is no evidence that indicates any impact to off-site biota. The acute and chronic fish toxicity tests further support the conclusion that LLNL storm water has no adverse effect on off-site biota.

All Site 300 cooling towers that discharge to surface were within their permitted limits for flow, pH, and TDS. All discharges from treatment facilities that discharge to surface were within their compliance limits. Thus, data indicate no impact to surface waters from LLNL Livermore site treatment facilities and Site 300 cooling towers.

7 Surface Water

LLNL maintains an extensive monitoring network for surface water, which includes treatment facility and cooling tower discharges, rainwater, storm water, and both on- and off-site drinking water and water bodies. The sample data indicate that the impact of LLNL Livermore site and Site 300 operations on off-site surface water is negligible.

8

Ground Water

Eric Christofferson
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Introduction

Ground waters in the Livermore Valley and in the Altamont Hills are sampled and analyzed regularly by Lawrence Livermore National Laboratory. The objectives are to:

1. Assess the progress of LLNL remediation efforts in areas of known ground water contamination.
2. Assess the effectiveness of current LLNL activities designed to protect the environment, especially waste management practices.
3. Conform with the requirements of the Ground Water Protection Management Program.

Remediation efforts result from LLNL actions to comply with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; see Chapter 2 for a summary of CERCLA activities). Operational monitoring complies with waste discharge requirements issued under California's Porter-Cologne Water Quality Control Act. Compliance monitoring is required by numerous federal and state controls (see Chapter 2, **Table 2-7**, for a summary of LLNL permits). Surveillance monitoring of ground water is performed to demonstrate compliance with DOE Order 5400.1, part of the U.S. Department of Energy's (DOE's) commitment to protect the environment at its sites.

For surveillance monitoring purposes, LLNL determines the number and locations of surveillance wells, the constituents of concern (COCs) to be monitored, the frequency of sampling, and the analytical methods to be used. This allows LLNL to design a comprehensive, cost-effective monitoring program. A wide range of COCs is monitored in ground water to confirm that current LLNL operations do not significantly impact local water resources. Because it looks at very low COC concentrations, surveillance monitoring can detect any slow-to-develop contamination resulting from past LLNL operations. Wells at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan. The surveillance networks include private off-site wells and on-site CERCLA wells.

8 Ground Water

Additional ground waters are monitored regularly at Site 300 to comply with state-issued permits associated with closed landfills containing solid wastes from past LLNL operations and with continuing discharges of liquid waste from current operations. This compliance monitoring uses networks of ground water wells that meet regulatory requirements.

LLNL's program of surveillance and compliance ground water monitoring follows an annual plan. Depending on their location and purpose, ground waters are sampled quarterly, semiannually, or annually for specific COCs. Standard operating procedures (SOPs) are followed when collecting samples of ground water to minimize the effects of sampling on analytical results (Dibley and Depue 1997).

Ground Water Regime

Livermore Site

Physiographic Setting

The Livermore Valley is the most prominent valley within the Diablo Range. It is an east-west trending structural and topographic trough bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 25 km long and averages 11 km in width. The valley floor is 220 m at its highest elevation along the eastern margin and gradually dips to 92 m at the southwest corner. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays with an average thickness of about 100 m.

The Livermore Valley Ground Water Basin encompasses 7700 hectares. The prominent streams are Arroyo del Valle, Arroyo Las Positas, Arroyo Seco, Arroyo Mocho, Alamo Creek, South San Ramon Creek, and Tassajara Creek. Arroyo del Valle and Arroyo Mocho drain the largest areas and are the largest streams. Arroyo Mocho now flows the entire year with water supplied by the Alameda County Flood Control and Water Conservation District Zone 7. The streams converge westward at Arroyo de la Laguna, which flows southward out of the valley into the Sunol Valley Ground Water Basin (Thorpe et al. 1990).

The Livermore Valley ground water system is a sequence of semiconfined aquifers. Ground water moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, ground water historically flowed south into the Sunol Valley Ground Water Basin. The largest quantities of ground water are pumped from the central and western portions of the Livermore Valley, where the valley fill is thickest.

The valley-fill sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium averages about 100 m in thickness. The alluvium is the principal water-producing formation within the valley.

The quality of ground water in the Livermore Valley reflects the surface water that recharges the aquifers. The chemical character of the ground water ranges from excellent (low sodium, magnesium, or calcium bicarbonate content) to poor (high sodium chloride content). In the eastern part of the valley, poor quality ground water results from recharge via Altamont Creek, which drains marine sediments to the east of the valley. High concentrations of naturally occurring minerals there, especially boron, render this ground water unsuitable for irrigation.

Drainage Retention Basin

In 1990, a drainage retention basin was constructed near the center of the Livermore site to catch and retain treated ground water and storm water runoff. The Drainage Retention Basin (DRB) is lined to prevent infiltration in this area. Surface drainage at the Livermore site is discussed in detail in Chapter 7.

Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on dominant particle size. Ground water flow beneath the site is primarily in sand and gravel lenses and channels, bounded by the less permeable clays and silts. The alluvial setting has been mapped into seven hydrostratigraphic units (HSUs) beneath the Livermore site using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation. HSUs 1B, 2, and 3A (in order of increasing depth, see **Figure 8-1**) contain contaminants, which are primarily solvents (Hoffman et al. 1998).

Based on borehole lithologic data, a series of buried sand and gravel-filled stream channels have been identified at the site. The sand and gravel deposits, which are highly permeable, are present in narrow bands at the site and are interpreted as braided stream deposits, similar to strata deposited by the present day Arroyo Mocho.

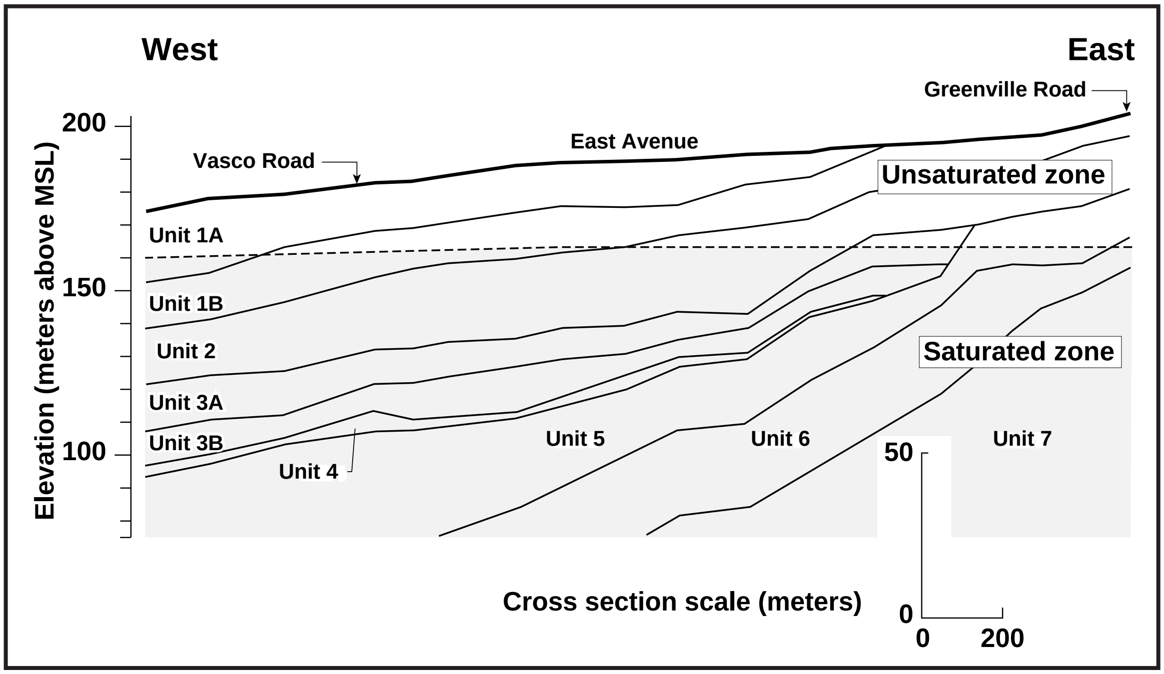

Figure 8-1. Cross section for the Livermore site showing hydrostratigraphic units.

In 1997, the depth to ground water below ground surface ranged from 34.5 m (113 ft, in HSU 5) at the southeast corner of the site to 6 m (20 ft, in HSU 1B) at the northwest corner and 11 m (37 ft, in HSU 2) at the northeast corner (Hoffman et al. 1998). Ground water levels have responded to variations in annual rainfall and resource use. Decreases in ground water use from the 1960s to 1985 caused the water table to rise. Heavy rains caused rises in 1986, 1993, 1994, 1995, 1996, and 1997 while drier-than-normal winters caused declines between 1987 and 1991.

Ground water is recharged at the Livermore site mainly from arroyos and from direct rainfall. Recharge enters primarily through the arroyos (see also Chapter 7). Ground water flow at the Livermore site is generally westward. The hydrogeology of the Livermore site is discussed in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and Ground Water Project reports.

The conceptual model presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* suggests that ground water generally flows towards two destinations from the Livermore site. Ground water from the north half flows west and northwest and eventually discharges to Arroyo Las Positas near First Street in Livermore, about 2 km northwest of the Livermore site. Ground water from the southern half flows generally westward toward the gap between the Mocho I and Mocho II subbasins, about 2 km west of the Livermore site. Ground water velocities at the Livermore site range from 15 to 20 m (49 to 66 ft) per year.

Site 300

Physiographic Setting

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east.

Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—Alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—Shallow marine and continental sedimentary and volcaniclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites); Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath the southeastern portion of Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has therefore been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* hereafter referred to as Final SWRI Report [Webster-Scholten 1994]). The Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300, underlying portions of the western and eastern General Services Area (GSA). The floodplain also makes small incursions into Site 300 in the vicinity of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, may locally influence ground water flow within the site and have therefore been studied as part of the CERCLA investigations.

Hydrogeology

Site 300 is semiarid, with an average annual rainfall of 27 cm (10.5 in). The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock comprises interbedded conglomerates, sandstones, siltstones, and claystones (**Figure 8-2**). Most ground water primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation (Tmss) Ground water can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season. Some ground water is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Buildings 833 and 834 areas, and in the Explosives Process Area. Fine-grained siltstone and claystone

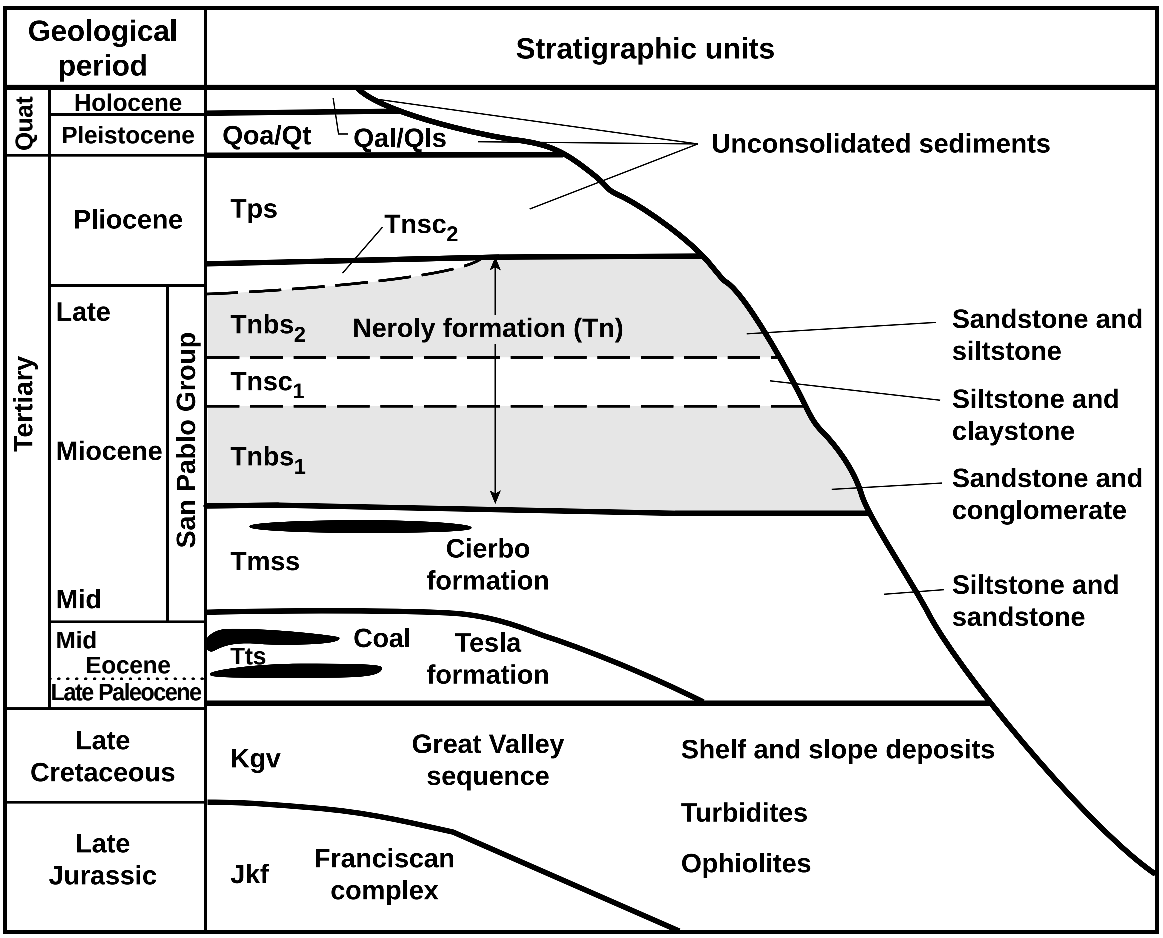

Figure 8-2. Site 300 stratigraphy. Stratigraphic codes are in standard geological notation (Webster-Scholten 1994). (For example, $Tnbs_1$ stands for the tertiary [circa 10 million-year-old] Neroly lower blue sandstone unit.)

interbeds in $Tnbs_1$ and Tmss act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in the southern half of the site, but is generally unconfined elsewhere.

Recharge occurs where saturated alluvium valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832 and Building 834 areas. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Ground water flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock ground water flows generally east-northeast. South of the anticline, bedrock ground water flows roughly south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 Area, and the southern part of the East Firing Area. The Tmss is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing areas. The thickness of the Cierbo Formation is not well-known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. Similar to the $Tnbs_1$, the continuity of saturation between the northwest and southeast areas of Site 300 is undetermined. Ground water in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, ground water is frequently perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Ground water in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300, but is saturated only in the Corral Hollow Creek stream channel, in Doall Ravine in the West Firing Area, and in southern Elk Ravine in the East Firing Area near a spring. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, the GSA, and in the Building 832 Canyon area; some of these ground water occurrences are ephemeral. Small quantities of ground water are present in some local landslide (Qls) deposits.

Surveillance Ground Water Monitoring of Livermore Valley

Livermore Site

LLNL Perimeter

To complement the Livermore Ground Water Project, LLNL designed the surveillance monitoring program to detect possible releases from beneath the Livermore site as a whole. The external portion of this surveillance ground water monitoring program makes use of two upgradient monitoring wells (W-008 and W-221) in the eastern portion of the site, and seven downgradient monitoring wells near and past the western boundary of the site (**Figure 8-3**). These downgradient wells are located in the regions of Treatment Facility A (W-121, W-151, and 14B1), Treatment Facility B (W-571 and W-1012), and Treatment Facility C (W-373 and W-556). This configuration was adopted in 1996

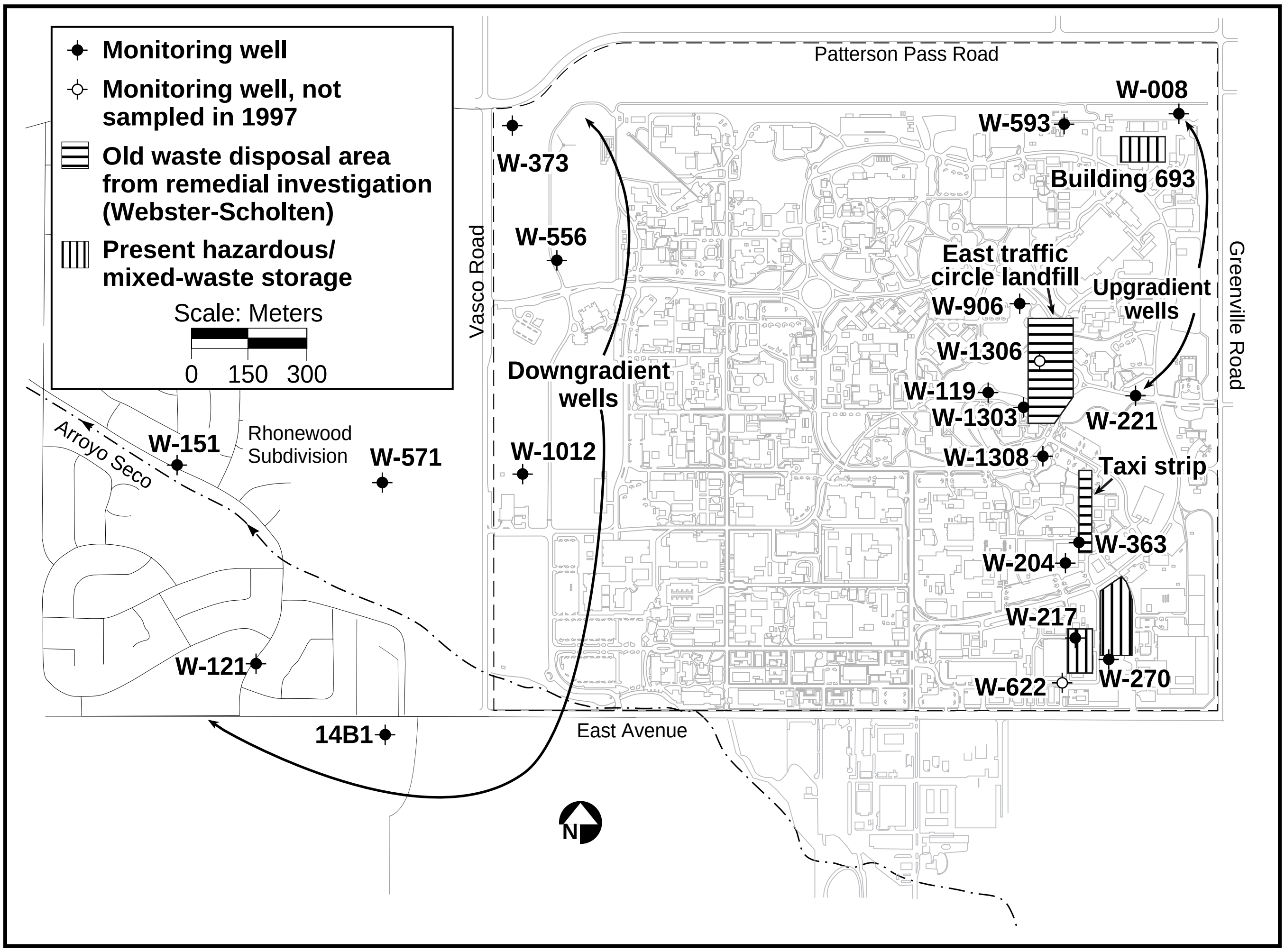

Figure 8-3. Locations of routine surveillance ground water monitoring wells at the Livermore site, 1997.

to monitor the uppermost aquifers (HSUs 1B and 2) within that area. The intent of this network is to monitor for possible contaminants other than volatile organic compounds (VOCs), which are handled under the Livermore Site Ground Water Project. These wells were sited to satisfy Resource Conservation and Recovery Act (RCRA) monitoring requirements and California Code of Regulations Title 22 monitoring requirements.

For the Livermore Ground Water Project, the constituents of concern (COCs) are VOCs, primarily trichloroethene (TCE) and tetrachloroethene (or perchloroethylene [PCE]). **Figure 8-4** shows the VOC isoconcentration contours in hydrostratigraphic unit (HSU) 2 in 1997. **Figure 8-5** shows a ground water elevation map for HSU 2 (Hoffman et al. 1998). This map shows that ground water within HSU 2 generally flows to the west-southwest toward Arroyo Seco during December and that cones of depression surrounding the treatment facilities are prominent. The cone of depression around Treatment Facility A, near Arroyo Seco, is especially prominent. Tables 8-1, 8-2,

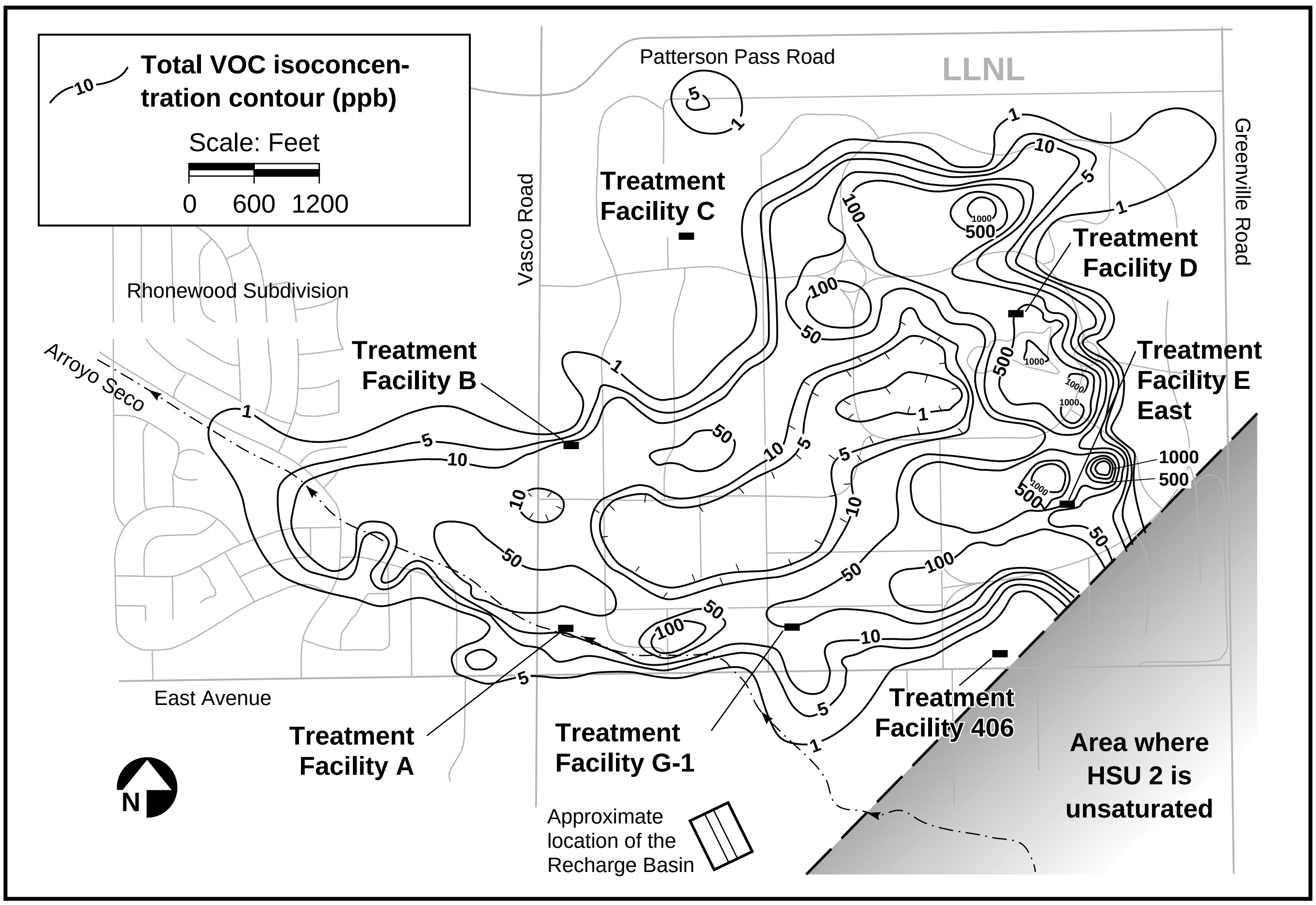

Figure 8-4. Distribution of VOCs for 170 sampling locations in hydrostratigraphic unit 2 (HSU 2), at Livermore site and vicinity, fourth quarter 1997.

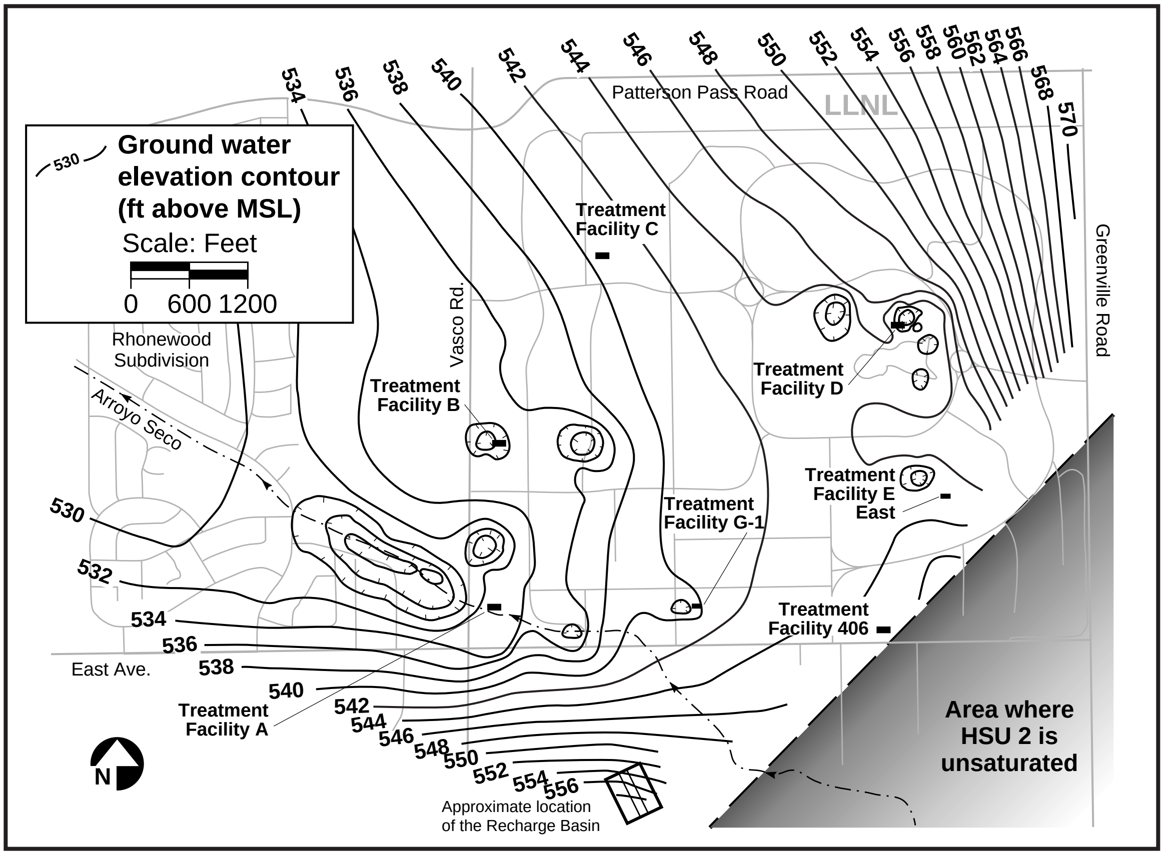

Figure 8-5. Ground water elevation contour map based on water levels collected from 152 wells completed within HSU 2, LLNL and vicinity, December 1997 (from Hoffman et al. 1998).

and 8-3 in the Data Supplement (formerly Volume 2) respectively show the analytical methods and reporting limits for inorganic constituents (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods), organic constituents, and radioactive constituents analyzed by gamma ray spectroscopy.

The two upgradient wells were sampled and analyzed quarterly in order to obtain sufficient data for statistical analyses; the seven downgradient wells were sampled and analyzed semiannually. Each well was sampled and analyzed for metals and minerals, gross alpha and beta, tritium, and radioisotopes. These routine surveillance monitoring analytical detections are presented in the Data Supplement (Tables 8-4 through 8-12). The second-year monitoring efforts will help establish baseline conditions for future monitoring and the presence of contaminants, including radioactive materials, in the ground water at levels of concern to public health or to the environment.

External Monitoring Results

Neither cyanide (via EPA Method 335.2), pesticides nor herbicides (via EPA Methods 547 and 632) were detected. Bis(2-ethylhexyl)phthalate, a plasticizer, was detected via EPA Method 507 for the first time in September samples collected from downgradient monitoring Wells W-556 and W-1012 near the western site boundary at concentrations of 5 µg/L and 21 µg/L, respectively. Butyl benzyl phthalate was detected in the method blank for both of these samples. Furthermore, bis(2-ethylhexyl)phthalate was not detected in the duplicate sample, also collected from Well W-1012. Di-*n*-octylphthalate, another plasticizer, was detected in a ground water sample collected from Well W-008 during the first quarter at a concentration of 12 µg/L. This compound was detected by EPA Method 625 for semivolatile organic compounds. Phthalate esters are common laboratory contaminants (see Dibley and Depue 1997). Benzoic acid was detected in monitoring Well W-373 in the northwest corner of the site. Concentrations detected in ground water samples were 39 µg/L and 57 µg/L in March and September samples, respectively. Although benzoic acid is a moderately strong organic acid, the lowest pH measured with a field meter in September was 7.19.

The inorganic compounds monitored in the ground water, including dissolved trace metals and minerals, are naturally occurring compounds at variable concentrations. **Table 8-1** shows the concentrations of four anions in the two upgradient wells and the seven perimeter downgradient wells. (See Tables 8-4 through 8-12 in the Data Supplement.)

Table 8-1. Concentration ranges for four anions in upgradient and downgradient monitoring wells.

	Concentration range (mg/L)			
Flow	Bicarbonate	Bromide	Chloride	Fluoride
Upgradient	121–350	0.76–1.7	272–498	0.71–1.4
Downgradient	180–260	0.24–0.71	75.5–160	0.21–0.95

Concentrations of boron are an order of magnitude higher in the upgradient wells, in the northeastern portions of the site, than in the downgradient wells. Boron reached a high concentration of 9.2 mg/L in monitoring Well W-008 in June 1997. This additional information further documents the poor ground water quality in the upgradient portions of the site put first discussed in Chapter 3 of the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990).

In 1996, nitrate was detected at concentrations ranging from 75 to 85 mg/L in ground water samples collected from monitoring Well W-1012 (screened in HSU 2). Concentrations of nitrates analyzed in water samples collected from this well in 1997 ranged from a high of 93.0 mg/L from a sample collected in March to a low of 76.6 mg/L from a sample collected in September (see the Data Supplement, Table 8-13). This is compared with nitrate concentrations ranging from 17.7 to 27 mg/L (see the Data Supplement, Table 8-5) from ground water samples collected from upgradient monitoring Well W-221 (screened in the adjacent HSU 3A). Well W-1012 lies within LLNL's boundary. Nitrate was found at a concentration of 31.4 mg/L in monitoring Well W-571, off site to the west about 300 m, in September 1997 (see the Data Supplement, Table 8-12). This is below California's drinking water maximum contaminant level (MCL) of 45 mg/L. Nitrate concentrations detected during 1997 monitoring range from 25.3 to 93 mg/L and are presented in the Data Supplement, Table 8-13. These nitrates may be agricultural residue according to the CERCLA report (Thorpe et al. 1990). Monitoring of these nitrates continues in 1998.

Concentrations of some nonradioactive dissolved metals detected in a few monitoring wells may be of concern. Dissolved chromium(VI) levels in monitoring Well W-373 remain at levels greater than California's MCL of 50 µg/L. (Dissolved chromium[VI] in all other wells monitored was found at concentrations less than the MCL.) Ground water in the area of Treatment Facility C has been treated for chromium(VI) since October 1993 (see Chapter 7). Dissolved nickel was detected at a concentration of 0.024 mg/L June 1996 (Harrach et al. 1997). During 1997, dissolved nickel was again detected in ground water samples collected from Well W-221. Nickel concentrations of 0.036 mg/L, 0.040 mg/L, and 0.013 mg/L were found in samples collected during the second, third, and fourth quarters, respectively. Ground water samples collected from Wells W-593 and W-1012 during 1997 contained nickel at concentrations from 0.003 mg/L to 0.007 mg/L. The primary drinking water MCL for nickel is 0.1 mg/L. Concentrations of the following dissolved metals were not detected above laboratory reporting limits during 1997: aluminum, antimony, arsenic, beryllium, cadmium, cobalt, lead, manganese, mercury, molybdenum, selenium, silver, and thallium.

None of the ground water samples from surveillance monitoring wells had concentrations of radioactivity or radioisotopes that exceeded a drinking water MCL. The highest tritium activity detected in 1997, 11.4 Bq/L (307 pCi/L), which is 1.5% of the tritium MCL, was found in monitoring Well W-373 (see the Data Supplement, Table 8-10).

Internal Monitoring

The succeeding locations, unlike the routine surveillance locations previously discussed, include areas where releases to ground may have occurred in the recent past. Monitoring wells screened in the uppermost aquifers are situated downgradient from, and as near as possible to, the potential release locations.

Two potential sources of ground water contamination, initially investigated prior to the remedial investigation (Thorpe et al. 1990), were added to the surveillance monitoring network during 1997 (see **Figure 8-3**). These areas are the Taxi Strip Area and the East Traffic Circle Landfill. Radioactively contaminated liquid wastes were deposited into four disposal pits in the Taxi Strip Area from 1953 through about 1976 (Thorpe et al. 1990). Contaminants detected in the soils were americium-241, uranium-235, cesium-137, cobalt-60, europium-152, thorium-232, unspecified transuranics, and VOCs (Buerer 1983). About 3000 cubic meters of contaminated soil and sediments were moved to the Nevada Test Site (Thorpe et al. 1990) when the area was cleaned up. Ground water samples from monitoring Wells W-204 (screened in HSU 2) and W-363 (screened in HSU 3A) downgradient from the Taxi Strip Area were collected and analyzed for plutonium, thorium, and uranium isotopes, and for radioisotopes via gamma spectroscopy during the third quarter of 1997. During 1998, ground water samples from these monitoring wells will be analyzed for the same radioisotopes, gross alpha/beta radiation, americium-241, radium-226, radium-228, tritium, strontium-90, dissolved metals, and general minerals.

Polychlorinated biphenyls (PCBs), nonradioactive metals, and various radionuclide contaminants were initially detected in the soil at the East Traffic Circle Landfill. Gamma spectroscopy revealed cesium-137, depleted uranium (D-38), radium-226, thorium-232, uranium-238, americium-241, and cobalt-60 in the soil (McConachie et al. 1986). LLNL collected and disposed of 11,000 cubic meters of debris and soil with metal shavings, broken bottles, and capacitors. Of this, approximately 6 cubic meters of material containing low-level radioactive waste was disposed of at the Nevada Test Site (Thorpe et al. 1990). Ground water samples from monitoring Wells W-119, W-906, W-1303, and W-1308 (screened in HSUs 2 and 3A) downgradient from the East Traffic Circle Landfill were collected and analyzed for plutonium, thorium, and uranium, and for radioisotopes via gamma spectroscopy during the third quarter of 1997. During 1998, ground water samples from these monitoring wells are being analyzed for gross alpha/beta radiation, radioisotopes, PCBs, dissolved metals, and general minerals.

All surveillance monitoring analytical data for the LLNL Taxi Strip Area and the East Traffic Circle Landfill are presented in the Data Supplement, Tables 8-15 through 8-20.

Another potential source of contamination is the Mixed-Waste Storage Facility present in the area of Building 693 (see **Figure 8-6**). Ground water samples were collected from monitoring Wells W-594, W-593, and W-007 (screened in HSUs 2 and 3A) downgradient from this facility during the third quarter of 1997. These samples were analyzed for plutonium, thorium, and uranium, and for radioisotopes via gamma spectroscopy. Those analytical results are presented in the Data Supplement, Tables 8-21 through 8-23. During 1998, ground water samples from monitoring Well W-593 (believed to provide

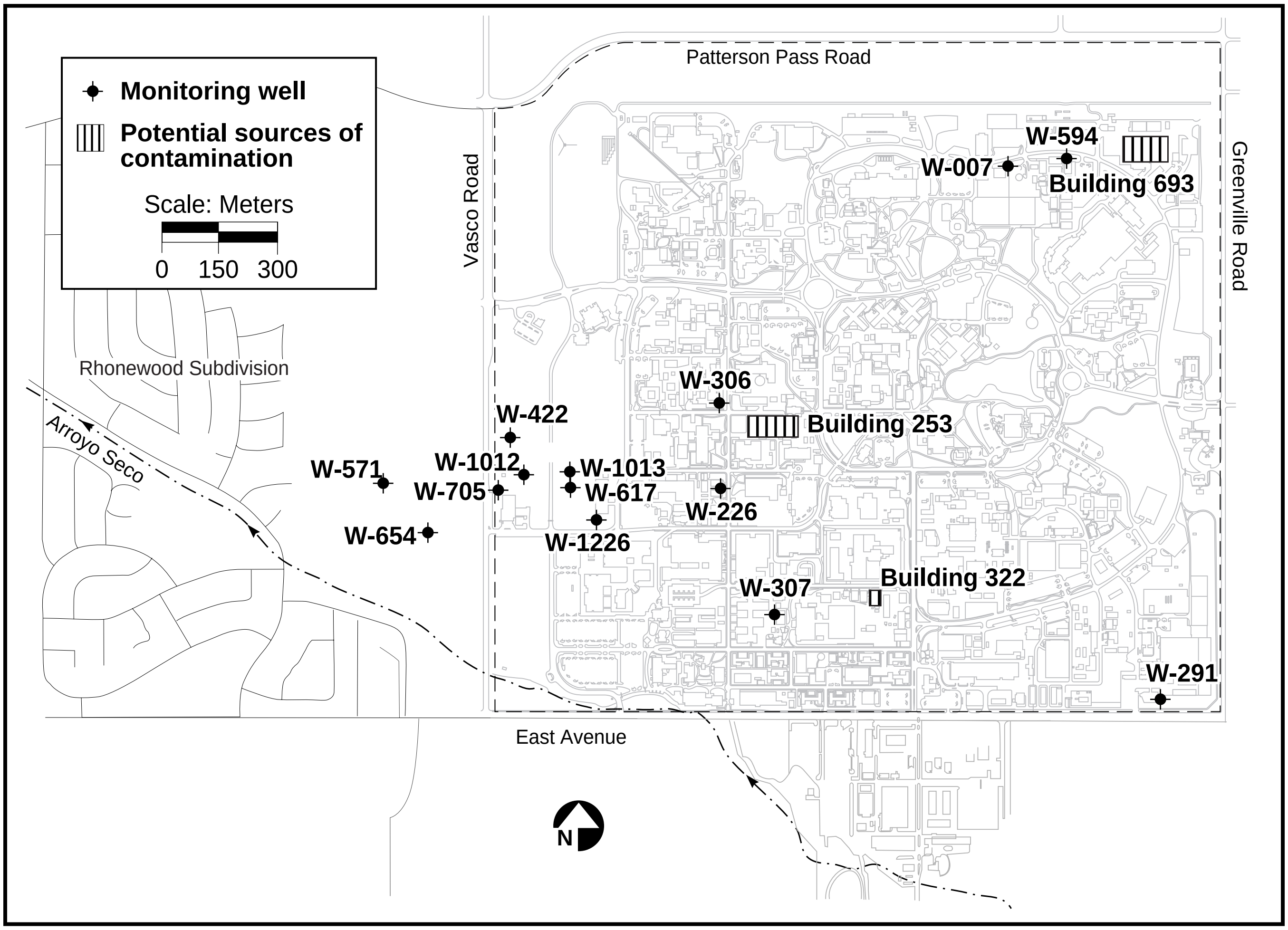

Figure 8-6. Locations of nonroutine surveillance ground water monitoring wells at the Livermore site, 1997.

the most representative ground water samples) are being analyzed for these same radioisotopes, gross alpha / beta radiation, americium-241, radium-226, radium-228, tritium, strontium-90, PCBs, dissolved metals, and general minerals.

During the first quarter, ground water samples were collected from monitoring Wells W-217 and W-270, downgradient from the Building 514 mixed-waste and hazardous waste storage area. These samples were analyzed for radium-226 and for radioisotopes via gamma spectroscopy to ensure that the hazardous and mixed-waste operations in this area have not added radioisotopes to ground water in concentrations harmful to humans or the environment. Analytical results are presented in the Data Supplement, Tables 8-24 and 8-25, respectively.

Ground water samples were also collected from the areas downgradient from two documented releases of metals to ground. Samples were collected from monitoring

Well W-307 (screened in HSU 1B), downgradient from where metals released from a fume hood on the roof of Building 322 leaked down onto the ground. Soil samples collected from the area of the Building 322 release showed elevated concentrations (in comparison with LLNL's site background levels) of chromium, copper, lead, nickel, zinc, and occasionally other metals (see the Data Supplement, Table 8-26). Ground water samples were also collected downgradient from where sediments containing metals (including mercury and chromium) had accumulated in a storm water catch basin near Building 253. These ground water samples were collected from monitoring Wells W-226 and W-306 screened in HSUs 1B and 2, respectively. Analytical results for dissolved metals for samples collected from those monitoring wells are presented in the Data Supplement, Tables 8-27 and 8-28. (See **Figure 8-6**.)

In addition, LLNL monitored several wells surrounding Well W-1012 that had elevated concentrations of nitrates (from 75 to 85 mg/L) in 1996 (Harrach et al. 1997). Analytical results of nitrate concentrations in ground water samples collected from monitoring Wells W-1012, W-1013, W-705, W-617, W-654, W-1226, and W-422 are presented in the Data Supplement, Table 8-13.

Internal Monitoring Results

Alpha spectroscopy is a very sensitive method of measurement for plutonium, thorium, and uranium activities. Uranium results are usually positive since uranium occurs naturally in the sediments at and surrounding LLNL. However, none have exceeded drinking water MCLs that have been measured to date. Plutonium radioisotopes were not detectable in filtered ground water samples, since plutonium is neither soluble nor mobile in the subsurface. However, thorium radioisotopes were detected in filtered ground water samples collected from Wells W-204, downgradient from the Taxi Strip Area, and W-594, downgradient from the Mixed-Waste Storage Unit near Building 693 (see the Data Supplement, Tables 8-15 and 8-21, respectively). No MCLs exist for thorium radioisotopes.

Analysis of ground water samples from the internal monitoring wells by gamma spectroscopy is intended to detect radioisotopes not detected by alpha spectroscopy. Gamma spectroscopy is not a sensitive analytical tool, especially with the low environmental levels of radioisotopes. Nearly every analytical result from gamma spectroscopy has positive results for the radioisotopes bismuth-214 and lead-214. Both are very short-lived radioactive daughters of the uranium-234–thorium-230–radium-226 series, and really indicate the presence of the parent radioisotopes rather than a release of the daughter isotope. In monitoring Well W-119, downgradient from the East Traffic Circle Landfill, gamma spectroscopy detected americium-241 at 0.34 Bq/L (9.1 pCi/L) (see the Data Supplement, Table 8-17), but with an estimated error of 100%. Another ground water sample was subsequently collected from this well and analyzed for americium-241 by the very sensitive alpha spectroscopy; the resulting calculated concentration was 0.002 Bq/L (0.06 pCi/L). Therefore, it is reasonable to assume that the activity for americium-241 estimated by gamma spectroscopy is invalid because of the large associated error.

Dissolved chromium was detected at elevated concentrations in Wells W-226 and W-306 downgradient from the area of the Building 253 catch basin. Chromium concentrations were 28 µg/L in Well W-226 and 46 µg/L in Well W-306. The sediments that had accumulated in the catch basin are a possible source of the chromium. Elevated concentrations of metals are absent in Well W-307 downgradient from the Building 322 release.

Off Site

LLNL has monitored tritium in water hydrologically downgradient of LLNL since 1988 (**Figure 8-7**). Tritium is potentially the most mobile contaminant emanating from LLNL in ground water. Rain and storm water runoff in the Livermore Valley recharges local aquifers and contains small amounts of tritium from natural sources, past world-wide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL and Sandia National Laboratories (SNL/California). (See Chapters 4, 5, and 7 for further discussion of air emissions, rain, and storm water runoff.)

Measurements in water samples collected during the summer of 1997 from 21 wells in the Livermore Valley show tritium levels were very low compared with the 740 Bq/L (20,000 pCi/L) MCL established by the State of California.

Tritium was measured at <1.20 to 2.77 Bq/L (<32.3 to 74.9 pCi/L) in ground water samples from on-site upgradient monitoring wells and from <1.15 to 11.4 Bq/L (<31.3 to 307 pCi/L) in external downgradient monitoring wells. The highest tritium activity measured off site was in a ground water sample from Well 12D2, located about 10 km west of LLNL. The activity in that sample in 1997 was 9.51 Bq/L (257 pCi/L). This represents a very slight increase of less than 4% from its measurement of 9.18 Bq/L (248 pCi/L) in 1996. However, tritium activity in ground water samples from Well 11B1 that had the highest tritium activity of 13.9 Bq/L (377 pCi/L) in 1996 decreased by more than 40% to a tritium activity of 8.29 Bq/L (224 pCi/L) in 1997. This is a slightly greater decrease than can be accounted for by simple radioactive decay. Dilution is another likely source of decreasing activities.

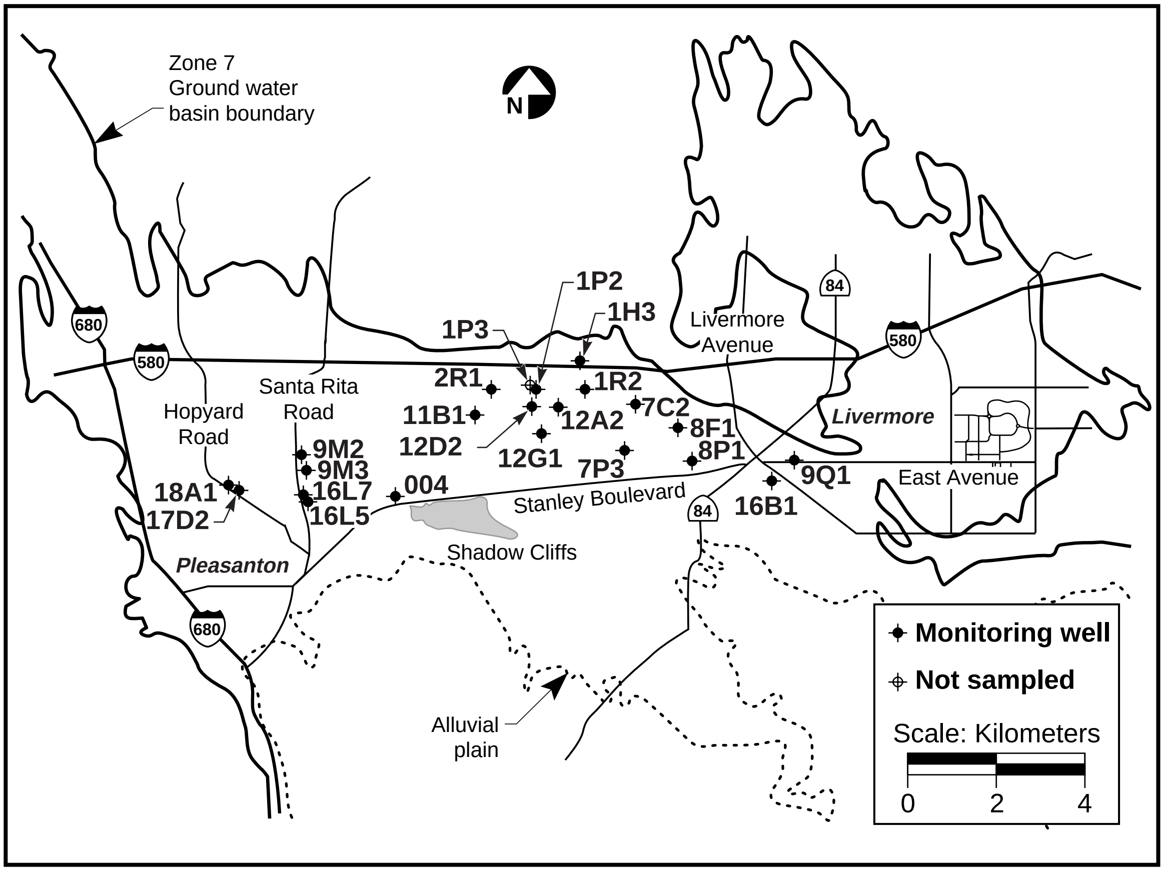

Figure 8-7. Locations of off-site surveillance ground water monitoring wells in the Livermore Valley.

Tritium activity has shown a decreasing trend overall in Livermore Valley ground waters downgradient of LLNL. The median activities of tritium in ground water samples from these downgradient wells increased from 3.45 Bq/L (93.2 pCi/L) in 1988 to 4.59 Bq/L (124 pCi/L) in 1989. By 1997, the median activity had dropped to 3.36 Bq/L (90.8 pCi/L), based on the 10 positive detections of tritium). This decrease in median activity is approximately equal to that expected through radioactive decay of tritium, which has a half-life of 12.3 years.

Surveillance Ground Water Monitoring of Site 300

Surveillance monitoring of ground water at Site 300 requires samples from DOE wells on site and from private wells off site. Ground water samples are routinely measured for the following COCs: various elements, primarily metals; a wide range of organic compounds; nitrate; general radioactivity (gross alpha and gross beta); uranium activity; and tritium activity. Analytical methods for COCs are selected for their high sensitivity.

Typically, EPA-approved methods are used for ground water analysis. (See the Data Supplement, Tables 8-1, 8-2 , and 8-3, for a complete list of COCs and the EPA methods, or other standard methods, used to measure COCs in ground water samples.)

Figure 8-8 shows 33 ground water sampling locations, which utilize wells and springs. At several locations there are as many as three distinct water-bearing zones. Although most of the sampling locations collect ground water from the uppermost water-bearing zone, four multiple-completion surveillance installations (K1-01, K1-02, K2-01, and K2-02) are fitted with Barcad devices that provide representative water samples from deeper water-bearing zones at those locations.

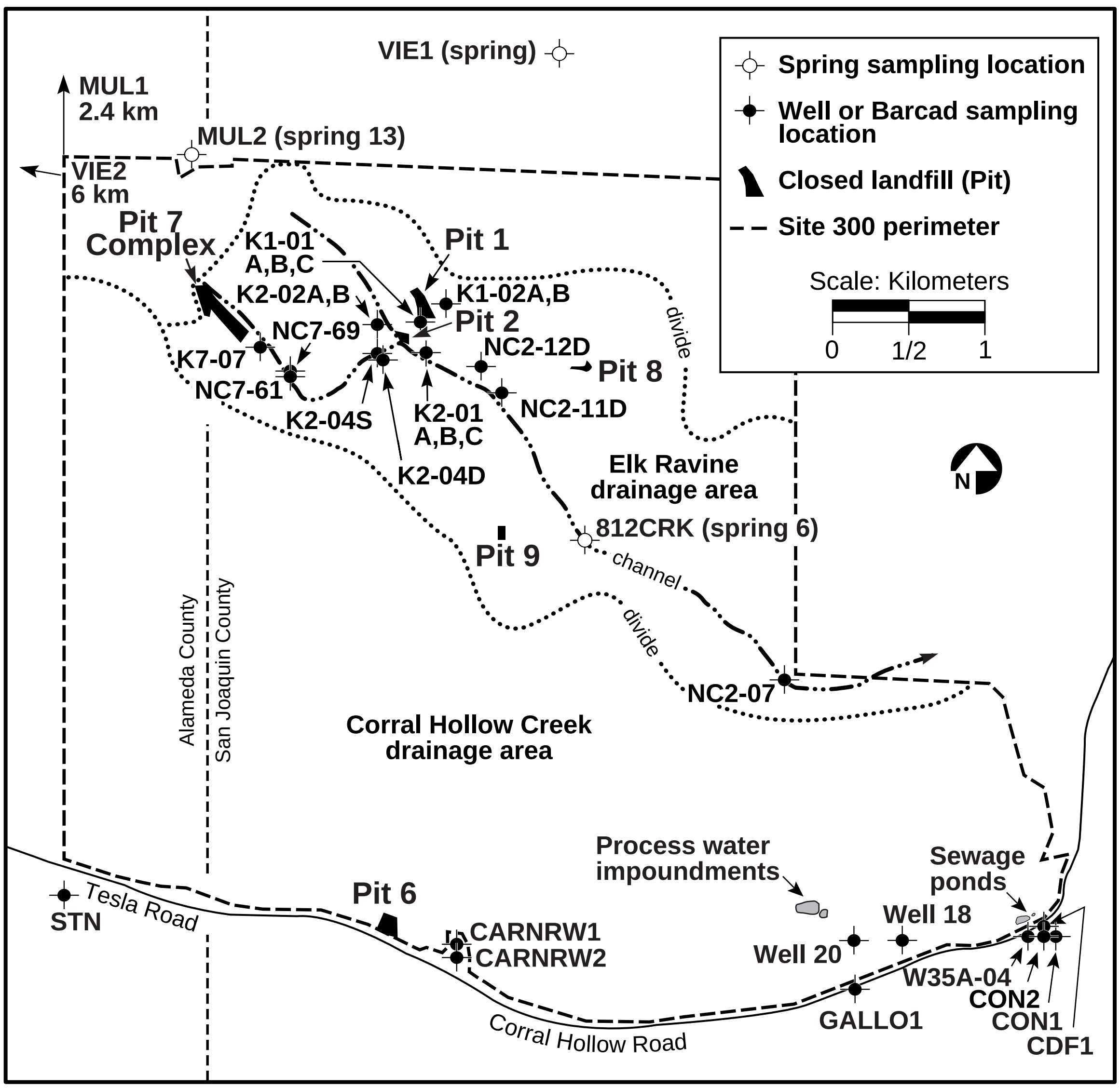

Figure 8-8. Locations of surveillance ground water wells, Barcads, and springs, Site 300, 1997.

Barcads are identified according to depth in **Figure 8-8** by the capital letters A, B, C, separated by commas at the end of an installation's identifier code. For multiple water-bearing zones, the Barcad that samples the deepest, or deeper, water-bearing zone is designated "A."

Of 31 surveillance sampling locations, 12 are off site. Three locations, including spring MUL2 and VIE1, are north of Site 300 in the Altamont hills. Well VIE2 is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. The remaining eight off-site surveillance locations are wells located immediately south of the Site 300 boundary in, or adjacent to, the Corral Hollow Creek floodplain.

Many on-site wells that were originally installed for CERCLA characterization studies during the 1980s remain in use as surveillance monitoring wells for several closed landfills (pits) that are not otherwise covered by WDR permits. Six wells monitor Pit 6. Five wells monitor Pit 8. Four wells monitor Pit 9. Seven Barcads in four multiple completions monitor Pit 2 (K2-01A and B, K2-02A and B, K1-01A and B, and K1-02A. Barcads K1-01C and K1-02B (**Figure 8-12**) monitor the uppermost water-bearing zone at Pit 1 for compliance purposes. Ten on-site surveillance locations, including one spring (812CRK), are located along the system of fault-marked ravines and arroyos that make up the Elk Ravine drainage area. Closed landfill Pits 1, 2, 3, 4, 5, 7, 8, and 9 are located in the Elk Ravine drainage area. Pit 6 lies in the Corral Hollow Creek drainage area. Surveillance monitoring also includes two on-site water production wells, Well 18 and Well 20. Well 20 provides potable water to Site 300. Well 18 is maintained as a standby supply well.

Brief descriptions of the surveillance networks are given below, together with a summary of ground water monitoring results for 1997. Tables of the ground water measurements made during 1997 are contained in the Data Supplement. Detailed descriptions of Site 300 geology, hydrogeology, and extent of ground water contamination can be found in Site 300 SWRI reports (Webster-Scholten 1994; Taffet et al. 1996).

Pit 6

The unlined, closed Pit 6 landfill covers an area of about 1 hectare adjacent to the southern boundary of Site 300 about 200 m above sea level (**Figures 8-8** and **8-9**). From 1964 to 1973, 1500 cubic meters (2000 cubic yards) of solid waste were buried in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 cubic meters (1700 cubic yards) of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 cubic meters (300 cubic yards) of biomedical waste,

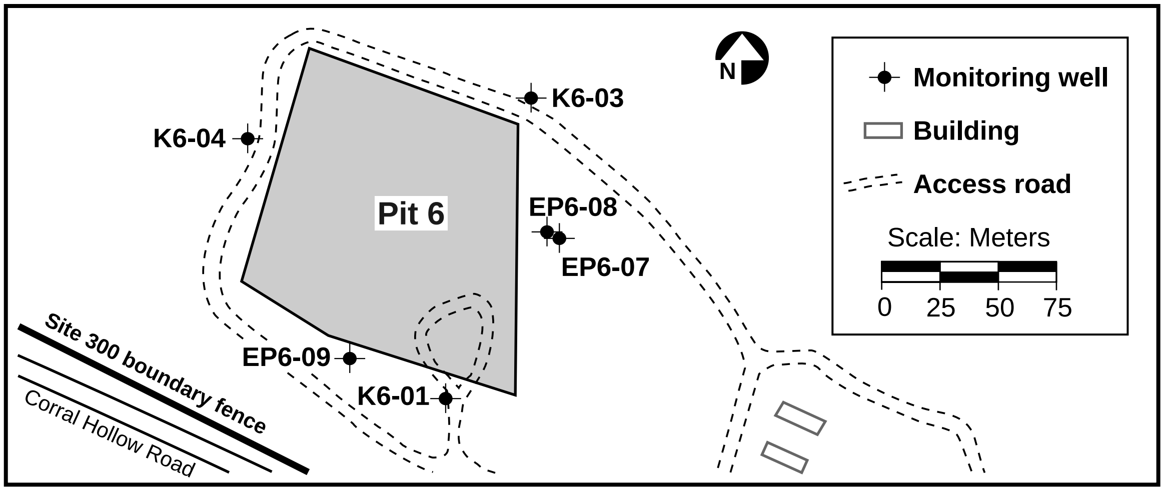

Figure 8-9. Locations of surveillance ground water monitoring wells, Pit 6, 1997.

including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over Pit 6, and a drainage control system was installed around the cap. The cap and drainage systems prevent rainwater from percolating through the buried waste.

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt in **Figure 8-2**) above and north of the Corral Hollow Creek floodplain. Tertiary Neroly sedimentary rocks ($Tnbs_1$ in **Figure 8-2**) lie beneath the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flows southward beneath the pit, following the south-dipping sedimentary rocks. Measured depths to the water table during 1997 were in the range of 10 to 20 m. Ground water flow turns southeastward beneath the southern margin of the landfill where movements along the Carnegie Fault have brought vertically dipping strata on the south into contact with the gently southward dipping strata to the north. A deposit of terrace gravel in a trough within the vertically dipping strata acts as a channel for the ground water after it passes beneath Pit 6 (Webster-Scholten 1994).

During 1997, six wells were used to collect ground water in the vicinity of Pit 6 for surveillance purposes (**Figure 8-9**). Well K6-03 is hydrologically upgradient from Pit 6, Wells K6-04, EP6-07, and EP6-08 are cross-gradient, and Wells EP6-09 and K6-01 are downgradient.

Surveillance ground water samples were collected twice during 1997 from the six monitoring wells. The samples were analyzed for 17 elements, mostly metals; nitrate; VOCs; pesticides and polychlorinated biphenyls (PCBs); explosives compounds; general radioactivity (gross alpha and gross beta); tritium (^3H) activity; and total uranium activity.

Analytical data are presented for each of the six monitoring wells in the Data Supplement, Tables 8-29 through 8-34. Metals were generally not detected above analytical reporting limits (RLs). Of the elements detected, only beryllium exceeded a maximum contaminant level (MCL) on one occasion, but this measurement was discounted, based on quality assurance data received from the analytical laboratory. Arsenic, barium, chromium, and selenium were detected at concentrations consistent with natural concentrations in the area ground water (Webster-Scholten 1994). Mercury was detected once at 0.24 µg/L, less than the MCL of 2.0 µg/L.

Trichloroethene (TCE) was detected at 16 µg/L, above its MCL of 5 µg/L in Well EP6-09 (see the Data Supplement, Table 8-34). This surveillance well monitors a shallow, slowly moving plume of TCE-bearing ground water that extends 125 m southeast from Pit 6, parallel to Corral Hollow Road (see Chapter 2, **Figure 2-2**). The TCE plume has been characterized, and its fate has been assessed in several CERCLA investigation reports (Webster-Scholten 1994; Ferry et al. 1998).

All surveillance network measurements during 1997 for gross alpha, gross beta, tritium, and uranium were at background activities, and were below their respective MCLs in drinking water. During 1997, tritium activity of about 50 Bq/L was measured in one CERCLA monitoring well, located about 25 m southeast of surveillance monitoring Wells EP6-07 and EP6-08. (For reference, the MCL for tritium is 740 Bq/L, and the background activity in the Pit 6 area is about 2 Bq/L.) The extent of the tritium-bearing ground water is probably very limited, because it is not detected above background in other nearby monitoring wells. A post-closure plan for monitoring TCE, tritium, and other COCs near Pit 6 using an expanded network of 28 CERCLA wells will be implemented the second quarter of 1998 (Ferry et al. 1998).

Pit 8

Pit 8 is located adjacent to the Building 801 firing table, where explosives experiments were conducted from 1958 to 1974. Approximately 40 cubic meters of untreated debris from the firing table was placed in the pit during that time, and a final cover was installed in 1974. Debris may contain HTO, depleted uranium (D-38), lead, and beryllium. The debris was originally dumped on the ground surface, which was later leveled and compacted by bulldozer. It was covered with about 1 m of locally obtained silt with small amounts of clay, sand, and gravel. A drainage ditch was constructed around the landfill to protect the cover from erosion.

Figure 8-10 shows the Building 801 and Pit 8 areas. The pit is located in a narrow ravine within the Elk Ravine drainage area about 330 m above sea level. It is bordered by an earthen dam on its west side at the locations of monitoring Wells K8-01 and K8-03.

Surficial materials at Pit 8 consist of colluvial soils and shallow ravine fills. The landfill was constructed in the unconsolidated Tps formation. Blue sandstone and interbedded siltstones and claystones of the Neroly Formation underlie the landfill area. The landfill is about 0.5 km northeast of the Elk Ravine fault shear zone, 1.2 km northeast of the Patterson anticline, and 0.5 km southwest of a subparallel syncline that plunges southeast. At the landfill, outcropping beds strike N25°W and dip slightly northeast. Chemical analysis of soil and rock samples collected from this area during CERCLA remedial investigations showed no elevated concentrations of COCs (Webster-Scholten, 1994). However, low concentrations of TCE have been detected in ground water samples from upgradient Well K8-01 since 1987.

The water table lies about 40 to 50 m below ground surface at Pit 8. Ground water flows east-northeasterly at a rate of about 20 m / year beneath Pit 8. Monitoring Wells K8-01 and K8-03B are hydrologically upgradient from Pit 8. Wells K8-02B, K8-04, and K8-05 are downgradient.

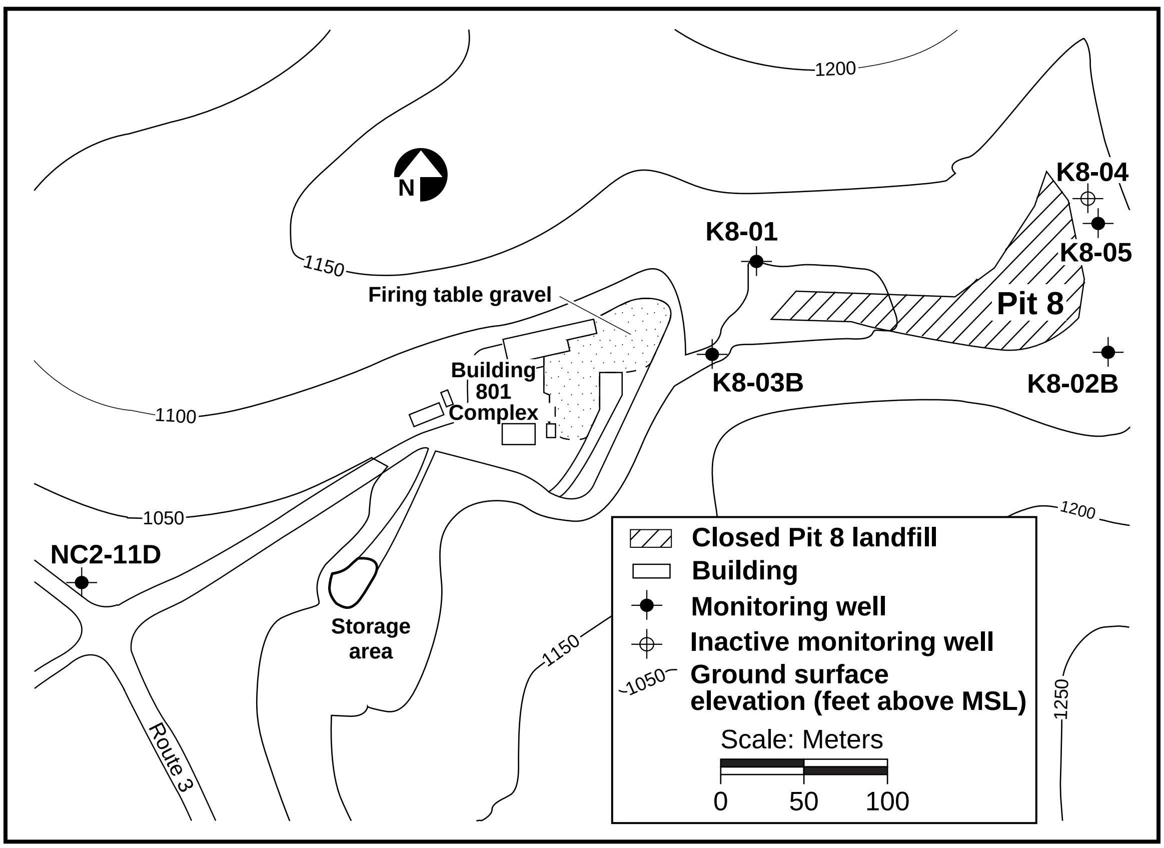

Figure 8-10. Locations of surveillance ground water monitoring wells, Pit 8, 1997.

Wells K8-01, K8-02B, and K8-03B produced sufficient sample water for analysis during 1997. Wells K8-01 and K8-02B were sampled twice. Well K8-03B was inaccessible during the second half of 1997 due to construction activities. Well K8-04 could not be sampled during 1997 because a bent casing prevented a bailer sampler from reaching ground water. Well K8-05 is screened in a perched water-bearing zone that did not yield sufficient water for analysis during 1997. Ground water samples were analyzed primarily for 17 elements (mostly metals). Volatile organic compounds (VOCs), tritium, and total uranium, were measured four times for Wells K8-01 and K8-02B. Gross alpha and gross beta were measured once in a ground water sample from Well K8-01. Analytical results for Pit 8 wells are shown in the Data Supplement, Table 8-35.

Arsenic, chromium, selenium, and vanadium were detected in concentrations similar to their natural abundances in ground water in the Altamont Hills. As in the past, the solvent TCE and its probable decomposition product, 1,2-DCA, were detected at levels approaching one half of their MCLs. The TCE is believed to have originated prior to 1981 in wastes discharged to a dry well upgradient from Pit 8 near Building 801 (Webster-Scholten 1994). No evidence for a release from Pit 8 is indicated by the monitoring data collected during 1997.

Pit 9

The inactive, closed Pit 9 landfill is centrally located within Site 300 about 340 m above sea level. Similar to the other closed landfills, the closed Pit 9 landfill contains firing table gravels with explosive experiment debris (mainly from the adjacent Building 845 firing table). Surface runoff from Pit 9 is northward to the Elk Ravine arroyo.

Figure 8-11 shows the locations of the four surveillance wells used to monitor the ground water in the vicinity of Pit 9. Ground water flows east-northeasterly beneath Pit 9 in the Neroly lower blue sandstone unit ($Tnbs_1$). The water table lies about 40 m below the ground surface at Pit 9. Monitoring Well K9-02 is hydrologically upgradient from Pit 9. Wells K9-01, K9-03, and K9-04 are downgradient.

Well K9-02 is screened at the contact between $Tnbs_1$ and Tmss. Wells K9-01, K9-03, and K9-04 are screened in Tmss, just below its contact with $Tnbs_1$.

For surveillance purposes, Pit 9 monitoring Wells K9-01, K9-02, and K9-03 were sampled once during 1997. The ground water samples were analyzed for 17 elements, mostly metals; nitrate; explosives compounds; volatile organic compounds; general radioactivity (gross alpha and gross beta); total uranium activity; and tritium (^3H) activity.

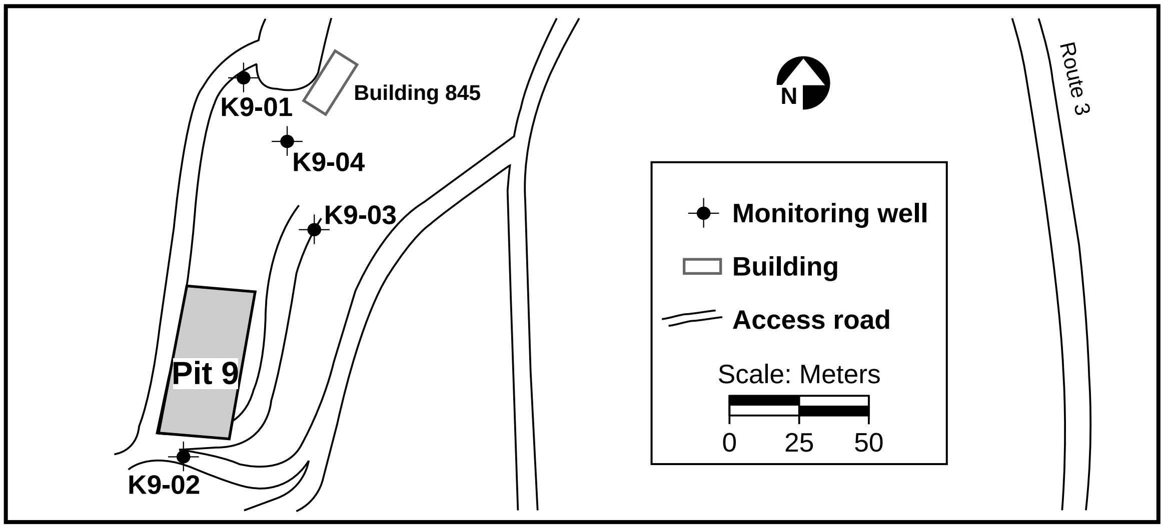

Figure 8-11. Locations of surveillance ground water monitoring wells, Pit 9, 1997.

Constituents of concern data for the four Pit 9 surveillance monitoring wells are presented in the Data Supplement, Table 8-36. No measurement exceeded an MCL for drinking water. COCs were either not detected, or were indistinguishable from natural background concentrations. No evidence for a release from Pit 9 is indicated by the monitoring data collected during 1997.

Pit 2

The unlined, closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figures 8-8** and **8-12**). The landfill primarily contains gravels and debris from hydrodynamic tests of explosive devices conducted at the Building 801 and 802 firing tables. The waste material contains depleted uranium (D-38), a manufactured form of uranium consisting mostly of the nonfissionable ^{238}U isotope. Trace amounts of beryllium, thorium, and tritium may also be present in the buried waste. Surface runoff from the Pit 2 area flows southerly into the Elk Ravine arroyo. Ground water flows east-northeast at a depth of about 25 m beneath Pit 2, following the dip of the $Tnbs_1$ and Tmss sedimentary rocks (**Figure 8-2**).

Multiple completion K1-01 is hydrologically downgradient from Pit 2. It contains one stovepipe well (K1-01C) and two Barcads (K1-01A and -01B, see **Figure 8-12**) that sample three separate water-bearing intervals within the underlying Tmss claystones and sandstones. Well K1-01C, which taps the shallowest water-bearing zone, also serves as one of two upgradient ground water monitoring points for the Pit 1 landfill to the

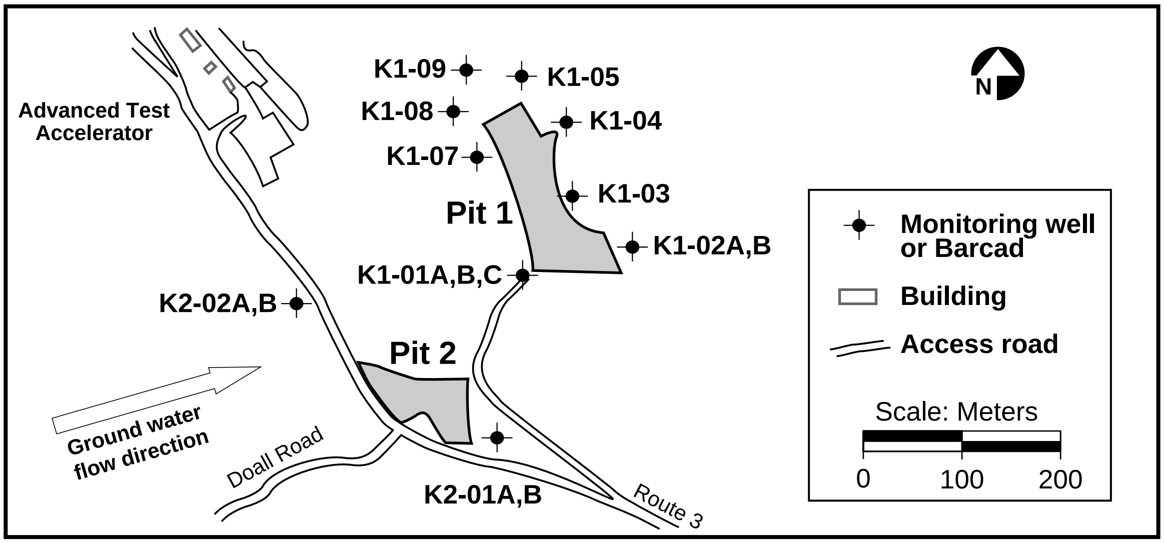

Figure 8-12. Locations of Pit 1 compliance ground water monitoring wells (K1-01C, -07, -02B, -03, -04, -05, -08, and -09) and Pit 2 surveillance Barcads (K1-01A and B, K1-02A, K2-01A and B, and K2-02A and B), 1997.

northeast of Pit 2. Multiple completions K2-01 and K2-02 are hydrologically cross-gradient from Pit 2, and water samples from them represent (presumably) the upgradient ground water. K2-01A, K2-02A, and Well K2-02B are screened in Tmss. Barcad K2-01B is screened in $Tnbs_1$.

For surveillance purposes at Pit 2, ground water samples were collected twice (semiannually) during 1997. Barcads K1-01A and -01B could only be sampled once during 1997. The Barcads became inoperative during the second half of 1997, a condition that persists and may not be correctable. Ground water samples collected from the Barcads and wells were analyzed for 17 elements, mostly metals; volatile organic compounds; nitrate; explosives compounds; general radioactivity (gross alpha and gross beta); tritium (^{3}H) activity; and total uranium activity.

Analytical data for the five Barcads and the wells are presented in the Data Supplement, Tables 8-37 through 8-43. Metals were generally not detected above analytical reporting limits. None exceeded a drinking water MCL. The arsenic and barium concentrations measured are within the range of natural background concentrations found in ground waters elsewhere at Site 300 and throughout the Altamont Hills (Webster-Scholten 1994).

The radioactivity and radioisotope measurements show only low background activities for gross alpha and gross beta. Tritium activities were at low background levels in all water-bearing zones near Pit 2 (~2 Bq/L), except for the intermediate zone sampled by Barcad K2-01B (7 Bq/L) (**Figure 8-8**). This activity is associated indirectly with a shallower plume of tritium-bearing water that extends from the Building 850 firing table to Pit 2 (see **Figure 8-13**) (Webster-Scholten 1994; Taffet et al. 1996). The incursion of the shallow, tritium-bearing ground water into the Pit 2 area is recorded in ground water samples from surveillance Well K2-01C that showed a tritium activity of about 550 Bq/L during 1997 (see Elk Ravine Drainage Area). The trace of tritium detected in the K1-02B sample suggests that the shallow and intermediate-depth water-bearing zones are weakly connected, perhaps along the nearby Elk Ravine fault. No evidence for a release of COCs to ground water from Pit 2 is indicated by the monitoring data collected during 1997.

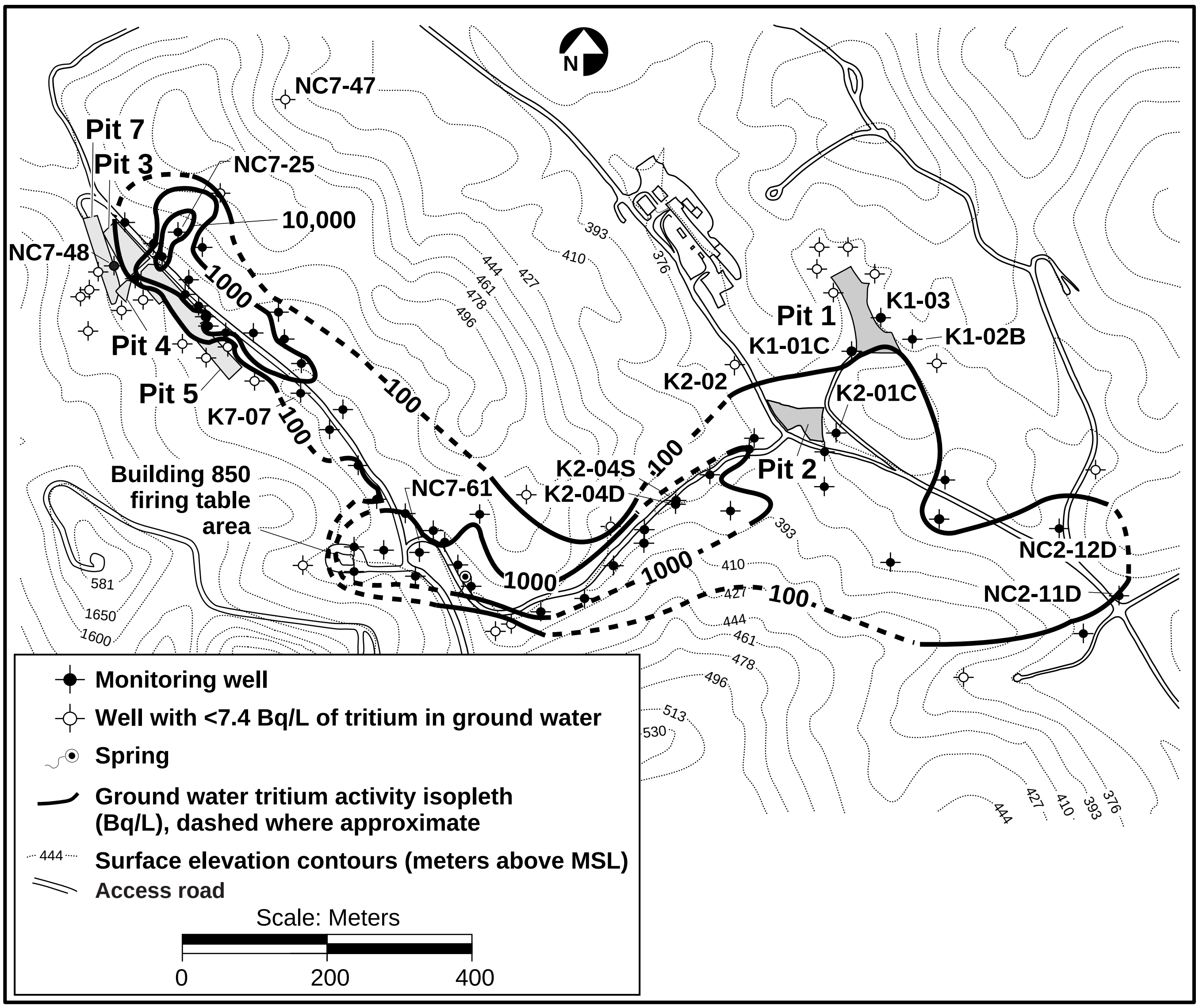

Figure 8-13. Map showing 1997 distribution of tritiated ground water extending from the Pit 7 Complex and the Building 850 firing table area to Doall Ravine and Elk Ravine, 1997.

Elk Ravine Drainage Area

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown in **Figure 8-8**. Surface runoff from closed landfills within the Elk Ravine drainage area (Pits 1, 2, 3, 4, 5, 7, 8, and 9) is collected in arroyos. Typically, surface water in arroyos infiltrates quickly. With sufficient seasonal rainfall, unconfined ground water can flow southeast on and within the Quaternary alluvial valley-fill deposits (Qal) that floor the Pit 7 Complex valley. Surface runoff from the Pit 7 Complex landfills at the highest elevation flows southeast to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit (Qls). At the northeastern end of Doall Ravine, this runoff combines with channeled runoff from the Advanced Test Accelerator (ATA) Building 865 area. From this confluence point, the arroyo trends southeasterly within Elk Ravine. Near Well NC2-07, channeled runoff turns easterly, away from the trend of the Elk Ravine fault, and flows off site for approximately 2 km to its confluence with Corral Hollow Creek. Except for Doall Ravine, the arroyos and valley-fill deposits traverse and follow faults, especially the extensive Elk Ravine Fault, which may provide pathways to the underlying ground water. Thus, ground waters from wells that lie within the Elk Ravine drainage area are monitored for COCs. The monitored wells are (from highest to lowest elevation) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, NC2-12D, NC2-11D, and NC2-07. The 812CRK sampling location is a natural spring (also known as Spring 6). It is located in the main Elk Ravine arroyo on the Elk Ravine Fault. Individual well locations are discussed below.

Well K7-07 is located in the Pit 7 Complex valley. It is a shallow well, screened in both $Tnbs_1$ and Qal. This well is cross-gradient from landfill Pits 3, 4, 5, and 7, with respect to unconfined flow in the valley-fill deposits (Qal) and to surface runoff. Wells NC7-61 and NC7-69 are screened in separate water-bearing zones beneath the upper reaches of Doall Ravine. Well NC7-61 is screened in $Tnbs_1$ (shallower zone), and Well NC7-69 is screened in Tmss (deeper zone). Wells K2-04D, K2-04S, and K2-01C are located near the intersection of Elk and Doall Ravines. They are screened in $Tnbs_1$. Wells NC2-12D and NC2-11D are located in Elk Ravine below its intersection with Doall Ravine. Well NC2-11D is screened at the contact between $Tnbs_1$ and Tmss. NC2-07 is the furthest downstream surveillance well in the Elk Ravine drainage area. It is screened in $Tnbs_1$.

For surveillance purposes, ground water samples were collected at six-month intervals (semiannually) during 1997 from monitoring wells in Elk Ravine and from the 812CRK spring. The samples were analyzed for 17 elements, mostly metals; explosive compounds; volatile organic compounds; nitrate; general radioactivity (gross alpha and gross beta); tritium (^3H) activity; and total uranium activity.

Surveillance analytical data for the ground water samples obtained during 1997 from monitoring wells in the Elk Ravine drainage area are given in the Data Supplement, Tables 8-44 through 8-53. Generally, surveillance monitoring of Elk Ravine during 1997 shows no evidence of any new or slow-to-develop release of COCs to ground water in this area, except for nitrate. Nitrate was measured above the MCL of 45 mg/L in two samples of ground water, one each from monitoring Wells NC7-61 and K2-04S. No VOCs or HE compounds were detected. None of the elements detected exceeded an MCL. Arsenic, barium, selenium, and vanadium were detected ubiquitously at low concentrations consistent with natural sources for these elements in the rocks. Gross alpha and beta activities were low and were indistinguishable from natural background, as was total uranium activity. Tritium activity was above background in many of the ground water samples.

LLNL remedial investigators have previously concluded that tritium, as tritiated water (HTO), is released occasionally from the Pit 3 and 5 landfills and soil moisture from beneath the firing table at Building 850. Tritiated water has been released from Pit 3 and Pit 5 during wetter-than-normal winters when ground water rises and contacts firing table wastes contained in these two unlined landfills. A major release of HTO occurred during the unusually wet winter of 1982/1983 (Webster-Scholten 1994), and additional releases occurred during the wet winters of 1986/1987, 1992/1993, 1994/1995, and 1995/1996 (Taffet et al. 1996). HTO is also transported to ground water beneath the Building 850 firing table gravels by percolating water from rain (Taffet et al. 1996). The configuration of the tritium-bearing ground water plumes at Site 300, updated for 1997, are shown in **Figure 8-13**. The HTO plumes are shallow and appear to be confined to the Neroly lower blue sandstone unit ($Tnbs_1$ and Qal). Continuing CERCLA studies show that despite additional releases the tritium contents and extents of the plumes are generally diminishing over time because of natural decay of tritium and dispersive mixing.

Wells 18 and 20

Wells 18 and 20 are located in the southeastern part of Site 300 (**Figure 8-8**). Both are deep, high-production water wells. Well 20 supplied potable water at the site during 1997, while Well 18 was maintained as a standby water supply well. Both wells are screened in the Neroly Formation lower blue sandstone unit ($Tnbs_1$). The Well 18 completion zone extends upwards into a fine-grained aquitard unit ($Tnsc_1$) in the Neroly Formation that separates $Tnbs_1$ from the overlying upper blue sandstone unit ($Tnbs_2$). Each well can produce up to 1500 L/min of potable water.

For surveillance purposes, ground water samples were collected quarterly from these two on-site supply wells. Water samples from Well 20 were analyzed for 17 elements, mostly metals; nitrate; explosives compounds, volatile organic compounds

(EPA Method 502.2); general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. Water samples from standby Well 18 were analyzed for volatile organic compounds (EPA Method 502.2); general radioactivity (gross alpha and gross beta); and tritium (^{3}H).

Surveillance analytical data for the two on-site potable water supply wells are presented in the Data Supplement, Tables 8-54 and 8-55. No metals of concern were detected in Well 20 during 1997, except zinc at 29 parts per billion (ppb) in the first-quarter water sample and chromium at 1.3 ppb in the third-quarter water sample. Both detections were far below MCLs of 5000 ppb for zinc and 50 ppb for chromium. Neither metal was detected above reporting limits of 20 ppb for zinc and 1 ppb for chromium during the second and fourth quarters.

As in past years, TCE was detected below the MCL of 5 ppb in the third and fourth quarter samples from Well 18, at 0.43 ppb and 0.86 ppb, respectively. The source of the TCE has not yet been identified.

Gross alpha, gross beta, and tritium activities in water samples from both production wells are very low and are indistinguishable from natural background activities.

Off-Site Supply Wells

For surveillance purposes during 1997, ground water samples were obtained from 12 off-site locations. Eleven of these locations are adjacent to Site 300. A distant well, VIE2, located at a private residence 6 km west of Site 300, is typical of potable water supply wells in the Altamont Hills. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight water production wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STN, and W-35A-04, are adjacent to the site on the south (**Figure 8-8**). W-35A-04 is a CERCLA well installed by LLNL for monitoring only. Wells CARNRW2, GALLO1, and STN supply potable water. Well CDF1 formerly supplied water for fire fighting.

Ground water samples were collected quarterly during 1997 at six off-site well locations. Of these, CARNRW1 and CON2 samples were analyzed only for volatile organic compounds (EPA Method 601), while CARNRW2, CDF1, CON1, and GALLO1 samples were analyzed quarterly for 17 elements, mostly metals; explosives compounds; volatile organic compounds; inorganic compounds; general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. Uranium activity was measured during the third and fourth quarters. Additional measurements of pesticides (EPA Method 608), herbicides (EPA Method 615), and semivolatile organic compounds (EPA Method 625) were made during the third quarter.

Ground water samples collected from six off-site locations—MUL1, MUL2, STN, VIE1, VIE2, and W-35A-04—were analyzed once (annually) during 1997 for 17 elements, mostly metals; nitrate; volatile organic compounds; semivolatile organic compounds, pesticides, herbicides, explosives compounds; general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. In addition to the analyses listed above, uranium isotope activities were determined for the MUL1 and STN ground water samples.

Surveillance analytical data for the 12 off-site water supply locations are presented in the Data Supplement, Tables 8-56 to 8-62. Generally, no COC positively attributable to LLNL activities was detected in the off-site ground water samples. Arsenic and barium were widely detected at these locations, but their concentrations were below MCLs and were consistent with natural sources in the rocks. Scattered detections of metals were all below MCLs and were probably related to metals used in pumps and supply piping.

Low concentrations of trihalomethanes (THMs) were detected in fourth-quarter water samples from the CARNRW2 monitoring well. The THMs are by-products produced by the chlorination units that purify water at Carnegie Park. The fourth quarter samples were collected downstream of the chlorination units.

As in past years, TCE was detected below the MCL of 5 ppb in the ground water samples collected from the GALLO1 surveillance well during the third and fourth quarters. LLNL remedial investigators concluded that the low concentration of TCE in the GALLO1 well water was probably due to a localized surface spill on the property, possibly from solvents used on a pump truck or another vehicle used to service the private well (Webster-Scholten 1994). Except for gross alpha in the annual STN well sample analysis, radioactivity measurements are indistinguishable from natural background activities. In the past, the STN well has shown elevated natural uranium activity. Total uranium activity for 1997 can account for the gross alpha activity, if the relatively large errors in the two different measurements are considered.

Ground Water Compliance Monitoring at Site 300

Ground water compliance monitoring at Site 300 is specified in Waste Discharge Requirement (WDR) orders issued by the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) and in Resource Conservation and Recovery Act (RCRA) Closure and Post-Closure Monitoring Plans (Rogers / Pacific Corporation 1990) approved by the California EPA Department of Toxic Substances Control (DTSC). The WDRs and post-closure plans specify the wells to be monitored, the COCs to be measured, measurement frequency, analytical methodology, and the frequency and form of required reports.

Ground water compliance monitoring programs are carried out at Site 300 in response to the LLNL Site 300 RCRA Closure and Post-Closure Monitoring Plan for Landfill Pits 1 and 7, and WDR Order Numbers 93-100 and 96-248. Compliance monitoring and reporting allow LLNL to evaluate operations of closed RCRA Landfill Pits 1 and 7, the Explosives Process Area Class II surface impoundments (hereafter surface impoundments), the sewage evaporation and percolation ponds (hereafter sewage ponds), and five percolation pits, and assure that they are consistent with regulatory requirements. WDR Order No. 93-100 and the Post-Closure Monitoring Plan establish the basis for the compliance monitoring network around Pits 1 and 7. Tables 8-63 to 8-66 in the Data Supplement list Pit 1 and 7 data pertaining to WDR Order No. 93-100 and post-closure monitoring. WDR Order No. 96-248 establishes the basis for compliance monitoring of the surface impoundments and the sewage ponds with their percolation pits. These monitoring programs include quarterly and semiannual monitoring of the ground water wells in each ground water monitoring network, monitoring of various influent waste streams to the surface impoundments and the sewage ponds, and visual observations of the sewage ponds and percolation pits. Each compliance monitoring network requires quarterly and annual reports of ground water analytical results, inspection findings, and maintenance activities.

Landfill Pits 1 and 7

Pit 1 Area

Figure 8-12 shows the RCRA-closed Pit 1 landfill and the eight compliance wells used to monitor the ground water in the vicinity of the inactive landfill. Pit 1 lies in the upper part of the Elk Ravine drainage area about 300 m above sea level. The RCRA cap constructed on Pit 1 in 1992 includes a layer of impermeable clay to prevent rainwater from infiltrating the landfill and potentially contacting the buried waste. A water-diversion channel made of concrete surrounds the landfill. Its purpose is to reduce local storm water infiltration by collecting runoff from the cap and the surrounding area and diverting it to Elk Ravine.

Ground water flows east-northeast beneath Pit 1, following the dip of the underlying sedimentary rocks. The eight Pit 1 compliance monitoring wells are used to collect representative ground water samples from the shallowest water-bearing zone, which is either in the Neroly Formation lower blue sandstone unit ($Tnbs_1$), or is beneath $Tnbs_1$ in the Cierbo Formation (Tmss in **Figure 8-2**).

With respect to Pit 1 and the direction of ground water flow, Wells K1-01C and K1-07 are hydrologically upgradient; Wells K1-02B, K1-03, K1-04, and K1-05 are downgradient; and K1-08 and K1-09 are cross-gradient.

For compliance monitoring purposes, representative samples of ground water were collected quarterly from Pit 1 monitoring wells and were analyzed for various COCs, fulfilling the requirements of WDR Order No. 93-100 Revision 1 (CVRWQCB 1993, 1996) and the RCRA Post-Closure Monitoring Plan (Rogers / Pacific Corporation 1990). Tables 8-63 and 8-64 in the Data Supplement contain the Pit 1 COC measurements made during 1997. Quarterly measurements were made for 10 elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium, radium-226, uranium (234, 235, and 238), and thorium (228 and 232) and explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]). The measurements of the three uranium isotope were summed to give total uranium activity. Semiannual measurements were made for an additional seven elements, mostly metals; pH; specific conductance; ground water elevation; and nitrate. Annual measurements were made for VOCs (EPA Method 601); purgeable organic compounds (EPA Method 624); extractable organic compounds (EPA Method 625); pesticides and PCBs (EPA Method 608); total dissolved solids (TDS); total organic carbon (TOC); and total organic halides (TOX).

Pit 7 Complex Area

Nine compliance wells monitor the Pit 7 Complex, which comprises four adjacent closed landfills (**Figure 8-14**). Pits 3, 4, and 5 were closed before RCRA became effective. Pit 7 was closed under RCRA during 1992 / 1993. The complex of closed landfills is located in the Pit 7 Complex valley about 400 m above sea level. From 1963 to 1988, the landfills received waste gravels from firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, depleted uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 cubic meters of gravel were removed from six firing tables at Site 300 and were placed in Pit 7 (Lamarre and Taffet 1989d). These were the last solid wastes to be placed in landfills at Site 300. (Since 1988, spent firing table gravel has been shipped to LLNL's Nevada Test Site for disposal.)

RCRA closure of Pit 7 was completed in February 1993. Closure included construction of an impermeable cap, runoff diversion channels, and a ground water interceptor trench to reduce local ground water recharge from rain. The RCRA cap over landfill Pit 7 also covers Pit 4 and about 30% of Pit 3.

Ground water beneath the Pit 7 Complex Area flows east-northeast, following the dip of the underlying sedimentary rocks.

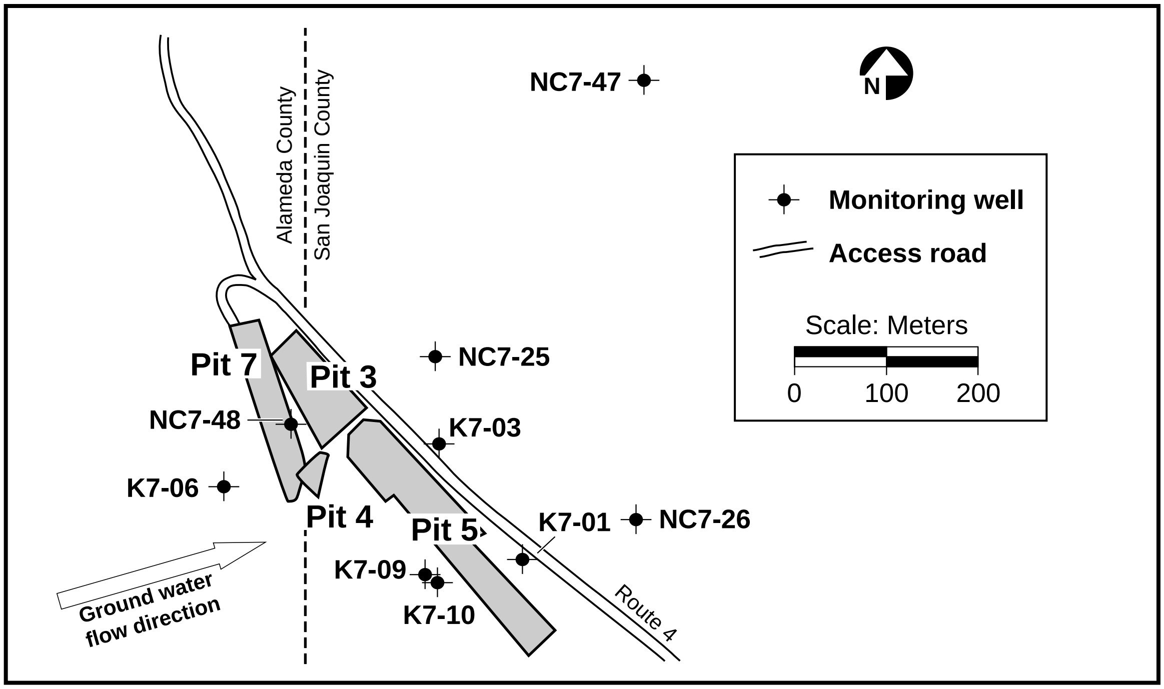

Figure 8-14. Locations of compliance ground water monitoring wells, Pit 7 Complex.

Monitoring Well K7-06 is hydrologically upgradient from Pit 7; wells K7-09 and K7-10 are cross-gradient; and wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are screened in the Neroly lower blue sandstone ($Tnbs_1$). The remaining wells are screened beneath $Tnbs_1$ in the Cierbo claystones and sandstones (Tmss).

Representative ground water samples were collected quarterly from Pit 7 monitoring wells and were analyzed for various COCs, fulfilling the requirements of WDR Order No. 93-100 Revision 1 (CVRWQCB 1993, 1996) and the RCRA Post-Closure Monitoring Plan (Rogers / Pacific Corporation 1990). The Pit 7 compliance analytical data for 1997 are presented in the Data Supplement, Tables 8-65 and 8-66. Quarterly measurements were made for 10 elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium, radium-226, uranium (234, 235, and 238), and thorium (228 and 232); explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]); volatile organic compounds (EPA Method 601); and ground water elevation. The measurements of the three uranium isotopes were summed to give total uranium activity.

Pit Monitoring Summary

Monitoring Well NC7-25 is located close to tritium sources in Pits 3 and 5 (**Figure 8-14**). The 1997 peak tritium activity was 27 times the MCL for tritium activity in drinking water. However, none of the wells in this area supplies water for purposes other than monitoring.

As in past years, four organic COCs were detected in the ground water at low concentrations during 1997. They are trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), trichlorofluoromethane (Freon 11), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113).

TCE was detected below the MCL of 5 µg/L in ground water at Pit 7 Wells K7-01 and K7-03. A TCE breakdown product, 1,1-DCE, was detected below the MCL of 6 µg/L in the ground water sampled at Pit 7 monitoring Well K7-03. Previous CERCLA investigations link the TCE in the ground water to wastes buried in Pit 5 (Webster-Scholten 1994; Taffet et al. 1996).

Freon 11 was detected below the MCL of 150 µg/L in ground water at Pit 7 Well NC7-48. Freon 11 has been detected at low concentrations since the second quarter of 1992. Pit 7 is the likely source of the Freon 11, because it is the only landfill upgradient of Well NC7-48.

Freon 113 was detected below the MCL of 1200 µg/L in the ground water at Pit 1 Wells K1-05 , K1-08, and K1-09. Previous CERCLA investigations link the Freon 113 to past spills in the ATA Building 865 area (Webster-Scholten 1994; Taffet et al. 1996).

Barium concentrations in the range of 70–80 µg/L exceeded the permitted statistical limit (SL) of 70 µg/L in the ground water at Pit 7 Well NC7-25. (For reference, the MCL for barium is 1000 µg/L.) CVRWQCB was notified by letter of this finding (Galles 1997). Previous CERCLA investigations conclude that, prior to capping Pit 7 in 1992, wastes buried there may have contributed additional barium to naturally occurring barium in the ground water (Taffet et al. 1996).

Tritium activity continued to exceed the permitted SL of 11.4 Bq/L in the ground water at Pit 1 monitoring Well K1-03. Previous CERCLA investigations link the tritium to a source beneath the Building 850 firing table area, about 1 km upgradient from Pit 1 (**Figure 8-13**).

During 1997, as in the past, tritium activities in ground water samples from three Pit 7 monitoring wells exceeded the 740 Bq/L drinking water MCL. These wells are K7-01, K7-03, and NC7-25. Previous CERCLA investigators conclude that tritium was released during the unusually wet winter of 1982/1983 from sources in Pits 3 and 5 (Webster-Scholten 1994) with additional minor releases occurring during the wet winters of 1985/1986, 1992/1993, and 1994/1995 (Taffet et al. 1996; Christofferson and MacQueen 1997). The highest tritium activity measured in a compliance monitoring ground water sample for 1997 was 19,800 Bq/L (27 times MCL) in a fourth-quarter sample collected from monitoring Well NC7-25 (**Figure 8-13**).

As has occurred in the past, total uranium activity exceeded the permitted SL of 1.22 Bq/L in the fourth-quarter ground water sample from Pit 7 Well NC7-25. Previous mass spectroscopy measurements at LLNL of ground water samples from Well NC7-25 show that uranium is present in the isotopic ratios of natural uranium, which indicates that this uranium probably came from natural sources in the rocks.

During 1997, as in the past, total uranium activity exceeded the MCL of 0.74 Bq/L, and gross alpha activity exceeded the MCL of 0.56 Bq/L in the ground water samples from Pit 7 Wells NC7-25 and NC7-48. Total uranium activity accounts for the gross alpha activity. Previous mass spectroscopy measurements of ground water samples from Well NC7-48 showed that the uranium present is a mixture of naturally occurring uranium and depleted uranium. Previous CERCLA studies conclude that depleted uranium has been released to ground water in the past from Pit 5 and from Pit 7 prior to its closure in 1993 (Taffet et al. 1996).

Surface Impoundments in Explosives Process Area

Release Detection

A three-tiered monitoring network is in place to detect releases of chemicals from the surface impoundments in the Explosives Process Area. The primary means of release detection consists of weekly visual inspections for leachate flow at the outfalls of perforated pipes installed in a sand layer between the inner impermeable layer liner of high-density polyethylene and an outer impermeable liner of compacted clay. Secondary release detection consists of quarterly inspections of lysimeters, installed beneath the clay liners, for the presence of liquids. Monitoring wells comprise a tertiary release detection system and a means of estimating the impact to ground water. Data pertaining to analyses of ground water samples collected beneath the surface impoundments are found in the Data Supplement, Tables 8-68 to 8-75.

Leachate Collection. The two leachate collection and removal systems were monitored for the presence of liquids, which would indicate a leak in a surface impoundment liner. As previously reported (Harrach et al. 1996), a leak was discovered in the upper surface impoundment’s polyethylene liner in June 1995. The leak allowed water to seep into a leachate collection pipe and from an outlet pipe into the lower surface impoundment. Repairs to the system were completed in December 1995. Water continued to flow from the upper surface impoundment’s leachate collection system until October 1996, when the leak rate fell to zero, where it has remained.

Over the course of 1997, LLNL tested an experimental electrical sensing system at the surface impoundments. This testing led to the discovery of a tear in the liner of the lower surface impoundment on September 12, 1997. Repairs were made on October 23. These repairs included patching the tear in the lower surface impoundment and rewelding a seam of the upper surface impoundment as a precautionary measure. No liquid has been collected in the system since these repairs were made.

Lysimeters. Five lysimeters installed in the vadose zone beneath the liners of the impoundments were operated quarterly during 1997 to extract water for analysis. No water was recovered. If water had been found in the lysimeters or the leachate collection systems, it would have been analyzed for aluminum, arsenic, barium, bicarbonate alkalinity, cadmium, calcium, carbonate alkalinity, chloride, chromium, cobalt, copper, fluoride, hydroxide alkalinity, iron, lead, magnesium, manganese, molybdenum, nickel, nitrate, pH, potassium, RDX, HMX, silver, sodium, specific conductance, sulfate, total dissolved solids, total alkalinity, total hardness, and zinc.

Monitoring Wells. The Monitoring and Reporting Program (MRP) for the surface impoundments, contained in WDR 96-248, requires that ground water samples be collected quarterly from four monitoring wells and establishes statistical concentration limits for COCs in ground water beneath the surface impoundments. The COCs and their concentration limits for ground water beneath the surface impoundments are contained in the Data Supplement, Tables 8-68 through 8-71.

MRP 96-248 requires compliance monitoring of the ground water underlying the two connected surface impoundments (**Figure 8-15**). The four ground water monitoring wells used are screened in the Neroly Formation upper blue sandstone layer ($Tnbs_2$). The direction of ground water flow is approximately southeasterly, following the local attitude (dip) of the formations. Well W-817-01 is hydrologically upgradient of the surface impoundments. Wells W-817-02, W-817-03, and W-817-04 are downgradient. Ground water samples are collected quarterly from these monitoring wells for analyses of the COCs specified in WDR 96-248. All 1997 analyses under MRP 96-248 for COCs and for other constituents, except for nondetections, are presented in the Data Supplement, Tables 8-68 through 8-75.

The high performance liquid chromatography method (EPA Method 8330) is used to analyze for energetic compounds. Analyses of ground water from upgradient monitoring Well W-817-01 indicated HMX at concentrations between 14 and 35 µg/L. HMX was not detected above the analytical reporting limit of 1 to 5 µg/L in any of the ground water samples from the downgradient monitoring wells. Ground water samples from three wells contained detectable concentrations of the energetic compound RDX above the analytical reporting limit of 0.85 µg/L. The ground water samples containing

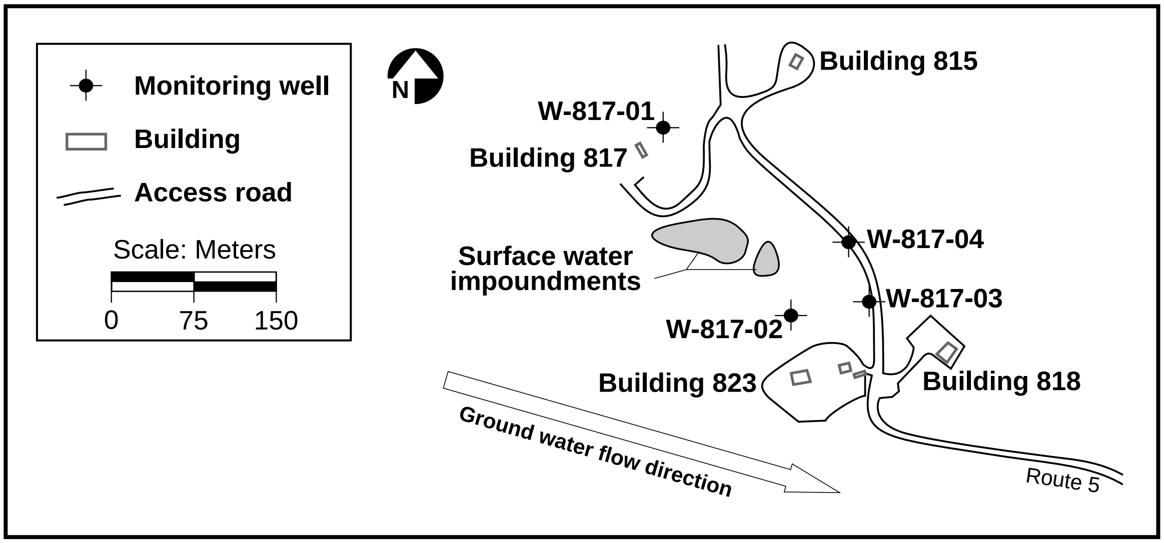

Figure 8-15. Locations of compliance ground water monitoring wells in the Explosives Process Area.

RDX were from upgradient Well W-817-01 (from 21 to 85 µg/L) and from downgradient Wells W-817-03 (5 to 8 µg/L) and W-817-04 (4.4 to 8.7 µg/L). RDX and HMX originate at closed disposal sites upgradient of the present surface impoundments (Raber and Carpenter 1983; Webster-Scholten 1994). The concentrations observed in the downgradient wells do not exceed their statistical limits (SLs). Additional compounds were detected by EPA Method 8330, but do not have SLs or MCLs, and are presented in the Data Supplement, Tables 8-72 through 8-75.

Ground water concentrations of TCE continued to exceed the drinking water MCL of 5 µg/L in samples from Wells W-817-03 and W-817-04 during 1997. The TCE detected in ground water samples from these wells has migrated in the ground water from past spills at Building 815, upgradient of the impoundments (Webster-Scholten 1994). No SL was developed for TCE, because it has not been discharged to the surface impoundments.

Ground water analyses of metals were carried out using inductively coupled plasma and graphite-furnace atomic-absorption spectroscopy EPA methods. Analyses of other inorganics were carried out using other EPA-approved methods. Ground water concentrations of arsenic and nitrates continued to exceed drinking water MCLs in samples from all the surface impoundment monitoring wells during 1997. Concentrations of both arsenic and nitrates in ground water have historically exceeded their respective MCLs (0.050 mg/L for arsenic and 45 mg/L for nitrates) in this area. Background concentrations of arsenic in ground water monitoring wells upgradient from the surface impoundments have been measured at concentrations above the drinking water MCL (Webster-Scholten 1994). Because of the wide range of measured concentrations, arsenic is the only compound for which statistical analysis of variance (ANOVA) is used each quarter to determine if a significant increase has occurred. For ANOVA, four individual samples are collected from each well and analyzed for arsenic. During 1997, ANOVA indicated some significant differences in arsenic concentrations upgradient and downgradient from the surface impoundments. Although the distribution of arsenic over time and throughout the area suggests a natural source, the occurrence and concentration of arsenic at Site 300 is the subject of an ongoing CERCLA study.

For the WDR 96-248 COCs, analytical results are in the Data Supplement, Tables 8-68 through 8-71.

Concentrations of zinc analyzed in ground water samples from monitoring Well W-817-02 have exceeded the SL of 0.076 mg/L for zinc since the fourth quarter of 1996. Like the arsenic discussed previously, this zinc exceedance of WDR permit limits resulted in the implementation of an overall CERCLA study of zinc occurrence and concentrations at Site 300.

Influent Monitoring

Photographic Process Rinse Water Discharges. WDR 96-248 established limits for discharges into the surface impoundments and required monitoring of the photoprocess and chemistry area wastewater retention tanks that discharge to the surface impoundments, as well as direct discharges occurring from the Explosives Process Area to the surface impoundments. During 1997, all discharges into the surface impoundments were consistent with discharge limits.

Retention tanks containing photographic process rinse water from Buildings 801, 823, 850, and 851 are sampled to confirm that discharges are consistent with the limitations specified in WDR 96-248. Discharges to the surface impoundments occur after samples are collected. Rinse water from the Building 823 retention tanks is discharged automatically to the surface impoundments. The Building 823 retention tank had two spills in 1997 (March 27 and July 16) due to equipment failures. These spills should have no impact on underlying ground water quality since the total volume spilled was only 26.5 liters (7 gallons) or less (see Chapter 2). Monitored constituents for the photographic processes were all below discharge concentration limits (see the Data Supplement, Tables 8-76 through 8-78).

Chemistry Area Wastewater Discharges. Wastewater from the Chemistry Area (Buildings 825, 826, and 827 Complex) is held in retention tanks until analytical results indicate compliance with the WDR permit. Analyses of discharges from the Chemistry Area during 1997 are presented in the Data Supplement, Table 8-79. Monitored constituents for the Chemistry Area discharges were all below discharge concentration limits.

Explosives Process Area Discharges. Process water discharges to the Explosives Area impoundments are analyzed for constituents that have been found (or are likely to be found) in the process water from each specified building within the Explosives Process Area. This monitoring program includes process area wastewater from Buildings 806/807, 809, and 817. WDR 96-248 requires annual analysis of this waste stream at Buildings 806/807, 809, and 817. A spill from the retention tank at Building 817 occurred on July 16 when the drain plugged with algae. This spill also had no impact on the underlying ground water because the total volume spilled was only 19 liters (5 gallons) (see Chapter 2). Explosives Process Area discharges from Building 809 were sampled in September 1997. Analytical results presented in the Data Supplement, Table 8-67, include metals, VOCs, semivolatile organic compounds, and energetic compounds. All monitored constituents were below discharge concentration limits.

Sewage Evaporation and Percolation Ponds

The environmental monitoring required for the sewage evaporation and percolation ponds is also specified in the MRP 96-248 contained in WDR 96-248.

Quarterly samples of wastewater flowing into the sewage evaporation pond are collected for analysis from a location upgradient of the pond in terms of sewage flow (sampling location ISWP). See **Figure 8-16.** The sample collection location is a manhole that captures all waste streams before they flow into the pond. The samples are analyzed for electrical conductivity or specific conductance, pH, and biochemical oxygen demand (BOD).

All required wastewater monitoring parameters for the sewage evaporation and percolation ponds were in compliance with specified limits throughout 1997. See **Tables 8-2** and **8-3**. The water level in the sewage evaporation pond was maintained below the minimum freeboard requirement of 0.61 m (2 ft). There were no discharges from the evaporation pond into the percolation pond during the year. Consequently, no samples were taken at the DSWP sampling location.

Ground water monitoring includes semiannual sampling and analysis from upgradient monitoring Wells W-7E, W-7ES, and W-7PS; from cross-gradient ground water monitoring Well W-35A-04; and from downgradient ground water monitoring Wells W-26R-01, W-26R-11, W-26R-05, W-25N-20, and W-7DS (**Figure 8-16**). Monitoring Wells W-7PS, W-26R-11, and W-35A-04 are screened in Quaternary alluvium (Qal); Wells W-7E and W-26R-01 are screened in the $Tnbs_1$; and the four remaining wells are screened in both Qal and $Tnbs_1$. Ground water samples were collected from the wells from April 28

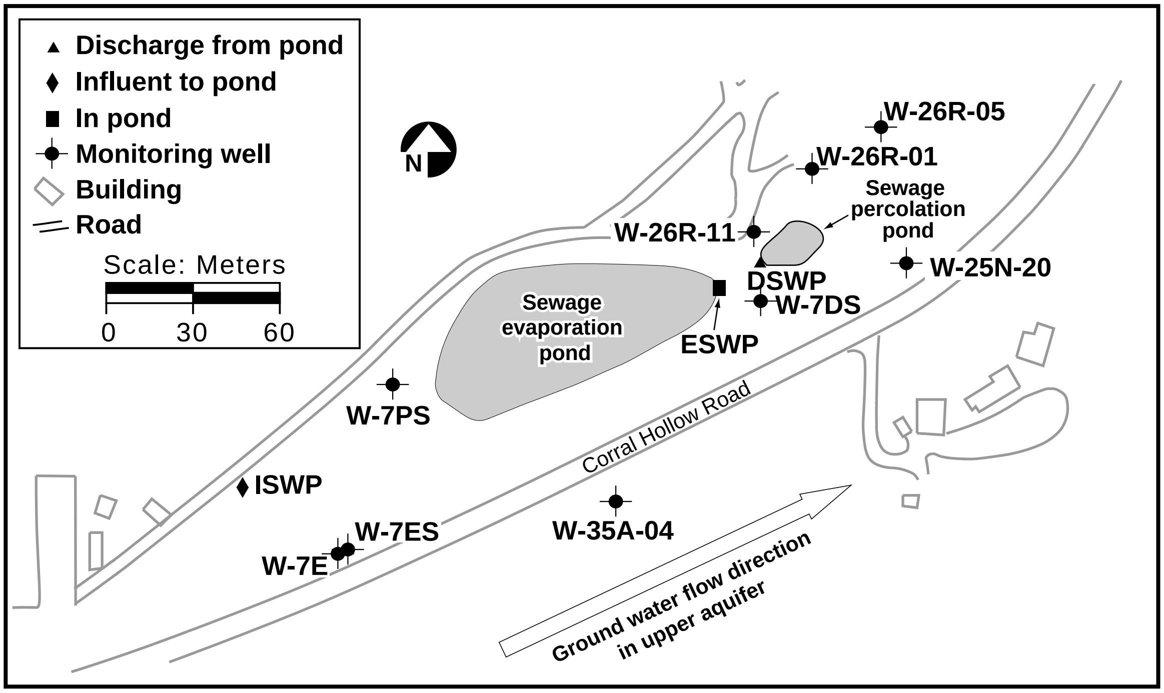

Figure 8-16. Locations of compliance ground water monitoring wells in the area of the sewage evaporation and percolation ponds.

Table 8-2. Sewage pond monitoring results, location ESWP.

Parameter	Permit limits	First quarter	Second quarter	Third quarter	Fourth quarter
pH (pH units)	none	10.0	10.0	9.3	9.8
Conductivity (µmho/cm)	none	5600	9100	12,000	10,000
Dissolved oxygen (mg/L)	1.0	24	9.4[(a)]	10/11.4[(b)]	16

a Field measurement reported. Laboratory analysis was invalid because the sample hold time was exceeded.

b The second number is the result of a field measurement the analytical laboratory staff conducted.

Table 8-3. Wastewater effluent monitoring results, location ISWP.

Parameter	Permit limits	First quarter	Second quarter	Third quarter	Fourth quarter
pH (pH units)	6.5 < pH < 10	8.3	8.4	8.3	8.1
Conductivity (µmho/cm)	none	2000	2000	2100	1500
Biochemical oxygen demand (mg/L)	none	500	230	500	240

through May 7, and again from November 3 through 19, and analyzed for conductivity, nitrate, total and fecal coliform, pH, and general minerals. The ground water analytical data for the sewage pond monitoring network are presented in the Data Supplement, Tables 8-80 and 8-81. All of the monitored constituents are in compliance with permitted limits.

MRP 96-248 requires monthly inspections of the percolation pits at Buildings 806A, 827A, 827C, 827D, and 827E. It also requires sampling and analysis for metals if an overflow occurs.

Monthly inspection reports for the percolation pits located at 806A, 827A, 827D, and 827E indicated that they performed as designed throughout 1997 and there were no overflows.

Ground Water Remediation

This section discusses monitoring directed by CERCLA ground water projects. Treatment Facility A (TFA) discharges to ground water are discussed here. Treatment facilities that discharge to surface water are discussed in Chapter 7.

Livermore Site

Treatment Facility A (TFA) is located in the southwestern part of LLNL near Vasco Road (**Figure 2-1**, Chapter 2). Waste Discharge Requirement (WDR) No. 88-075 requires a sampling program for TFA (**Table 8-4**). From 1989 to mid-1997, VOCs were removed from ground water using UV / H_2O_2 treatment technology and an air stripper. In June 1997, this system was replaced with a large capacity air-stripping system. In operation since September 1989, TFA has treated more than 1400 ML of ground water, removing about 93 kg of VOC mass from the subsurface. During 1997, TFA treated about 480 ML of ground water containing an estimated 18 kg of VOCs. Treated ground water was discharged to the Recharge Basin located about 600 m southeast of TFA on DOE SNL / California property (**Figure 8-4**).

On several occasions in 1997, while attempting to maximize ground water treatment and capture with the UV / H2O2 system, TFA exceeded its waste discharge requirement (WDR) limit of 5 ppb total VOCs in ground water effluent. These discharges were reported to the Regional Water Quality Control Board, and at no time did VOCs in TFA discharge exceed a maximum contaminant level (MCL). Since startup of the new system, TFA has not exceeded the 5 ppb total VOC WDR limit.

Table 8-4. Treated ground water discharge limits identified in WDR Order No. 88-075 for Treatment Facility A (TFA).

Constituent	Discharge limit[a]
Metals (μg/L)	
Antimony	1460
Arsenic	500
Beryllium	0.68
Boron	7000
Cadmium	100
Chromium(III)	1700×10^3
Chromium(VI)	500
Copper	2000
Iron	3000
Lead	500
Manganese	500
Mercury	20
Nickel	134
Selenium	100
Silver	500
Thallium	130
Zinc	20,000
Volatile organic compounds (μg/L)	
Total volatile organic compounds	5
Acid extractable organic compounds (μg/L)	
2,4-Dimethylphenol	400
Phenol	5
2,4,6-Trichlorophenol	5
Base/neutral extractable organic compounds (μg/L)	
1,4-Dichlorobenzene	5
Naphthalene	620
Phenanthrene	5
Pyrene	5

a These limits are instantaneous maximum values.

Site 300

Building 834 Complex. The Building 834 Complex is located in the eastern portion of Site 300. An isolated, perched, water-bearing zone that contains TCE in excess of the MCL of 5 ppb has been defined and reported (Bryn et al. 1990; Landgraf et al. 1994). The TCE remediation system at this site is operated as a CERCLA Removal Action. Ground water treatment and discharge is monitored in compliance with Central Valley RWQCB

Substantive Requirements for the Building 834 Removal Action. Air emissions are stipulated to be no greater than 6 ppm/hr, and are regulated under an Authority to Construct permit from the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). Limitations on effluents discharged from ground water treatment operations are listed in **Table 8-5**.

Table 8-5. Site 300 Building 834 ground water treatment surface discharge effluent limitations.

Parameter	Building 834 Treatment Facility
VOCs[a]	
Maximum daily (per compound)	5.0 µg/L
Monthly median	0.5 µg/L
pH	Between 6.5 and 8.5
Location discharge	Treated effluent will be discharged by air misting east of Building 834.
Total petroleum hydrocarbons	
Daily maximum contaminant level	100 µg/L
Monthly median	50 µg/L
Flow rate (30-day average daily dry weather maximum discharge limit)	7580 L
Mineralization	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits	
VOCs	Method EPA 601/602[b]
Tetrabutyl orthosilicate (TBOS)	Modified EPA Method 8015, discharge limit = 100 µg/L[c]

a The sum of VOC concentrations in a single sample shall not exceed 5.0 µg/L and the monthly median value of the sum of VOC concentrations shall not exceed 0.5 µg/L.

b Confirmatory VOC identifications were sometimes required during treatment facility characterization, and EPA 624 analyses were requested in addition to the EPA 601/602 analyses.

c Detection limits for TBOS are currently ~100 µg/L by a modified EPA 8015 procedure.

Ground Water Protection Management Program

LLNL's Ground Water Protection Management Program (GWPMP) is a multifaceted effort to eliminate or minimize adverse impacts of LLNL operations on ground water (Brandstetter 1997). U.S. Department of Energy (DOE) Order 5400.1 and the to-be promulgated 10 CFR 834 require all DOE facilities to prepare a GWPMP that describes the site's ground water regime, and areas of known contamination and remediation activities and programs to monitor the ground water and monitor and control potential sources of ground water contamination. Much of the ground water monitoring and remediation at the Livermore site is carried out under CERCLA restoration efforts, and the Livermore Site Ground Water Project and is summarized in Chapter 2 of this volume. This section describes LLNL's efforts to comply with DOE Order 5400.10.

Areas of Special Concern

The objectives of the GWPMP include monitoring the impact of current operations and eliminating or minimizing adverse impacts from ongoing operations on ground water. The approach is to detect contaminants before they can enter the ground water. In order to determine the areas with the greatest potential to contaminate ground water, LLNL evaluated the following three factors:

1. Current processes and operations that could contaminate areas where there is rapid communication between surface water and ground water.
2. Current and planned best management practices (BMPs) that minimize the risk of ground water contamination.
3. Current and new monitoring to provide early warning of potential ground water contamination.

With these considerations, five areas have been identified as being at risk for ground water contamination:

- The arroyos (Arroyo Las Positas and Arroyo Seco) that cross the site.
- The storm drain system.
- Soil around underground storage tanks.
- Soil around the sanitary sewer systems.
- The ground water beneath the hazardous waste management (HWM) buildings, Building 514 and Building 612, that may be subject to spills.

Soil and Sediment Surveillance Monitoring

Soil monitoring in the arroyos and storm water network was one of the items targeted in the GWPMP surveillance monitoring because "...recharge of natural runoff through the stream beds of arroyos accounts for the majority (about 42%) of resupply to the Livermore Valley ground water basin..." (Webster-Scholten 1994). Infiltrating rainwater may carry with it any dissolved constituents that may be present. Programs already exist that address the sanitary sewer system, the building drains, and underground storage tanks.

LLNL has developed background levels for total and soluble metals in soils and sediments (**Table 8-6**) and de minimis (or designated) concentrations for soluble metals (**Table 8-7**) and organics (**Table 8-8**) (Folks 1997; Marshack 1991). Soils with total metal concentrations below background and no detected organics are considered acceptable for reuse on site. If the concentration for a metal is above the total metal background value, then the soluble concentration for the metal is compared to the soluble background value. If the metal concentration is below the soluble metal background value, the soil is acceptable for reuse on site. If a metal exceeds both the total and soluble background values, or if there are any detected organics, the designated level methodology (DLM) described below is used to determine the soluble levels of contaminants that would not adversely impact ground water beyond its beneficial uses by application of a simple attenuation factor and

Table 8-6. Background screening concentration values for metals in soils at the Livermore site.

Metal	Background screening value	Metal	Background screening value
Total (mg/kg)		**Soluble (mg/L)**	
Antimony	1.12	Antimony	Any detection
Arsenic	8.51	Arsenic	0.237
Barium	308	Barium	16.7
Beryllium	0.62	Beryllium	Any detection
Cadmium	1.59	Boron	To be determined
Chromium	72.4	Cadmium	Any detection
Chromium(VI)	Any detection	Chromium	0.727
Cobalt	14.6	Cobalt	0.985
Copper	62.5	Copper	2.6
Lead	43.7	Iron	To be determined
Mercury	0.14	Lead	0.987
Molybdenum	Any detection	Manganese	To be determined
Nickel	82.8	Mercury	0.0063
Selenium	Any detection	Molybdenum	Any detection
Silver	Any detection	Nickel	1.68
Thallium	Any detection	Selenium	Any detection
Vanadium	65.2	Silver	Any detection
Zinc	75.3	Thallium	Any detection
		Vanadium	1.22
		Zinc	4.52

Table 8-7. De minimis concentration levels for metals found in Livermore site soils.

Constituent	Water quality objective (mg/L)	Reference	Attenuation factor	De minimis level (mg/L)
Metals				
Antimony	0.006	Cal Primary MCL	100	0.06
Arsenic	0.050	Cal Primary MCL	100	0.5
Barium	1.0	Cal Primary MCL	100	10
Beryllium	0.004	Cal Primary MCL	100	0.04
Cadmium	0.005	Cal Primary MCL	100	0.05
Chromium	0.05	Cal Primary MCL	100	0.5
Cobalt	5	RWQCB Basin Plan	100	50
Copper	1	RWQCB Basin Plan	1000	100[a]
Lead	0.015	EPA	1000	1.5
Mercury	0.002	Cal Primary MCL	100	0.02
Molybdenum	0.05	RWQCB Basin Plan	100	0.5
Nickel	0.1	Cal Primary MCL	100	1
Selenium	0.05	Cal Primary MCL	100	0.5
Silver	0.1	Cal Secondary MCL	100	1
Thallium	0.002	Cal Primary MCL	100	0.02
Vanadium	1	RWQCB Basin Plan	100	10
Zinc	5	Cal Secondary MCL	1000	500[a]

a Hazardous waste limit is 25 mg/L for copper and 250 mg/L for zinc. Soils with soluble concentrations at or above these values would be disposed of as a hazardous waste and not reused on site.

specific water quality objectives. The San Francisco Bay RWQCB and LLNL agreed upon an attenuation factor of 100 except for certain metals; the attenuation factor for copper, lead and zinc is 1000. Any constituents with soluble concentrations above these de minimis levels may adversely impact the ground water beneath. LLNL has developed and the San Francisco Bay RWQCB has approved this site-specific DLM for beneficial reuse of soils generated from construction projects at the Livermore site. If the concentration of a constituent in soil is above its background level, the DLM can be used to determine if the constituent will adversely affect ground water quality. This same process is applied below to determine if constituent concentrations in arroyo sediments are protective of ground water quality.

Table 8-8. De minimis concentration levels for nonmetal constituents of concern found in Livermore site soils.

Constituent	Water quality objective	Reference	Attenuation factor	De minimis level
Organics (µg/L)				
1,2-Dichlorobenzene	600	EPA Primary MCL	100	3000
1,3-Dichlorobenzene	130	CA DHS Action Level	100	650
1-4-Dichlorobenzene	5	Cal Primary MCL	100	25
1,1-Dichloroethane	5	Cal Primary MCL	100	25
1-2-Dichloroethane	0.5	Cal Primary MCL	100	2.5
1,1-Dichloroethene	6	Cal Primary MCL	100	30
1,2-Dichloroethene	6	Cal Primary MCL	100	30
cis-1,2-Dichloroethene	6	Cal Primary MCL	100	30
trans-1,2-Dichloroethene	10	Cal Primary MCL	100	50
1,1,1-Trichloroethane	200	Cal Primary MCL	100	1000
1,1,2-Trichloroethane	5	Cal Primary MCL	100	25
Benzene	1	Cal Primary MCL	100	5
Carbon tetrachloride	0.5	Cal Primary MCL	100	2.5
Chloroform	100	EPA Primary MCL	100	500
Diesel oil/kerosene	100	SNARL[(a)]	100	500
Ethyl benzene	700	Cal Primary MCL	100	3500
Freon 11 (trichlorofluoromethane)	150	Cal Primary MCL	100	750
Freon 12 (dichlorodifluoromethane)	1000	CA DHS Action Level	100	5000
Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane)	1200	Cal Primary MCL	100	6000
Gasoline	5	Other[(b)]	100	25
Methylene chloride	5	Cal Primary MCL	100	25
MTBE	35	CA DHS Action Level	100	175
Oil and grease	25,000	Other	100	125,000
Tetrachloroethene (PCE)	5	Cal Primary MCL	100	25
Toluene	150	Cal Primary MCL	100	750
Trichloroethene (TCE)	5	Cal Primary MCL	100	25
Xylene(s)	1750	Cal Primary MCL	100	8750
PCB (total)	0.5	Cal Primary MCL	100	2.5
Vinyl chloride	0.5	Cal Primary MCL	100	2.5
Radioactivity (BqL)				
Gross alpha	0.56	Cal Primary MCL	100	5.6
Gross beta	1.9	Cal Primary MCL	100	19
Tritium	740	Cal Primary MCL	100	7400

[a] SNARL = Suggested No Adverse Response Level.

[b] Other = Taste and odor threshold for gasoline, and the California Ocean Plan Water Quality Objectives for Oil and Grease.

In 1997, LLNL sampled sediments in the shallow vadose zones in the arroyos at three influent locations (ASS2, ALPE, and GRNE), the two effluent locations (ASW and WPDC), and two on-site locations (CDB and EDB) in the settling basins upstream of the Drainage Retention Basin (see **Figure 9-3**, Chapter 9). Samples were analyzed for organics using EPA Method 8240 for both total and soluble metals using California's Waste Extraction Test (see Tables 8-82 to 8-84 in the Data Supplement). Analytical results for a variety of radioisotopes are summarized in Chapter 9, Soil and Sediment Monitoring, **Table 9-1**. Radiological analyses were also conducted at additional locations. In this section, arroyo sediment sample results are discussed; for a description of methods and a discussion of 1997 soil and sediment sampling radiological results, see Chapter 9.

No organic constituents were detected in 1997 arroyo sediment sampling. Total barium, selenium, and silver concentrations were above their respective total background concentrations in one sample each, but in all three cases the soluble concentrations were below the soluble background values. Therefore, these constituent concentrations are no threat to ground water quality. In addition, the detection limit for one total beryllium analysis and for all total antimony analyses were higher than the background value. However, in each case the soluble concentration was below the soluble background value, again indicating that these constituent concentrations are protective of ground water quality.

For radioisotopes, LLNL has developed de minimis levels for tritium and for gross alpha and gross beta radiation. All tritium results were below the de minimis levels (gross alpha and gross beta radiation analyses were not conducted in 1997). Thus, the sediment data indicate no adverse impact on ground water through the arroyos that cross the Livermore site.

CERCLA Remedial Actions

Livermore Site

An extensive investigation of the remediation options for the contaminated areas discussed above is summarized in the *CERCLA Feasibility Study Report for the LLNL Livermore Site* (Isherwood et al. 1990). *The Record of Decision for the Lawrence Livermore National Laboratory Livermore Site* (U.S. Department of Energy 1992) documents the remedial options selected for implementation. The selected remedies for ground water contamination involve pumping the ground water to the surface for treatment with a combination of ultraviolet light/hydrogen peroxide, air stripping, and granulated activated carbon. The selected remedies for contaminants in the unsaturated zone are vacuum-induced venting with surface treatment of the vapors by catalytic oxidation or activated-carbon filtration. The goal of the remedial action is to clean the ground water to the levels specified in the applicable, relevant, and appropriate requirements developed for this project and outlined in the Record of Decision (ROD). A description of the remediation efforts during 1997 can be found in Chapter 2 of this report.

Site 300

Investigation of the remediation options for the contaminated areas at Site 300 is discussed in the Final SWRI Report (Webster-Scholten 1994). It includes a thorough compilation of all pre-1992 ground water and soil investigation information for the entire site and contains a detailed assessment of potential human health and ecological hazards or risks resulting from contamination of soil, rock, and ground water. New characterization, summary, and feasibility study or engineering evaluation/cost analysis reports have been, or will be, prepared for portions of the individual study areas, where the Final SWRI Report or more recent studies indicate that unacceptable potential hazards or risks exist. A summary of the remediation efforts and studies conducted during 1997 can be found in Chapter 2 of this report.

Environmental Impacts

The impact of LLNL Livermore site and Site 300 operations on off-site ground waters is minimal. With the exception of VOCs being remediated under CERCLA at both sites, LLNL operations appear to have little or no adverse effect on the surrounding ground waters.

Livermore Site

Ground water monitoring at the LLNL Livermore site and in the Livermore Valley indicates that LLNL operations, both past and present, have minimal impact on ground water beyond the site boundary. VOC plumes that were advancing to the west and southwest are being pulled back to the site and treated.

During 1997, concentrations of no compound or element detected in ground water in any off-site well monitored exceeded primary drinking water MCLs for any of the monitored constituents. None of the analytical measurements of radioactivity exceeded MCLs. The maximum tritium activity of 11.4 Bq/L (307 pCi/L), only 1.5% of the MCL, was detected in the ground water sample collected from on-site Well W-373 in September. The maximum tritium activity measured off site in the Livermore Valley was only 9.5 Bq/L (257 pCi/L), in 1997.

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs, with the exceptions of chromium in monitoring Well W-373 and nitrates in monitoring

Well W-1012. Chromium(VI) in ground water in the vicinity of monitoring Well W-373 is being treated in Treatment Facility C (TFC), and this treatment is monitored separately. The LLNL Ground Water Project reports on the treatment of ground water in the vicinity of the treatment facilities. Ground water samples collected from Well W-1012 in March, June, and September 1997 all exceeded California's MCL of 45 mg/L. Nitrates above the MCL have not migrated off site. An investigation to determine the source of nitrate in the vicinity of Well W-1012 is continuing in 1998.

Site 300

Ground water monitoring at Site 300 and adjacent properties in the Altamont Hills shows that past and present LLNL operations have minimal impact on ground water beyond the site boundaries.

VOCs, primarily the solvent TCE, have been released historically to shallow ground water at numerous locations at Site 300 (see Chapter 2, **Figure 2-2**; Webster-Scholten 1994; Taffet et al. 1996; Ferry et al. 1998; and references cited therein). With the exceptions of the two small plumes in the General Services Area (GSA) area that extend minimally off site along Corral Hollow Road, all of the TCE-bearing ground water is on site. The plume extending off site from the Eastern GSA area is being pumped back to the site and cleansed of TCE.

Tritiated water and depleted uranium have been released to ground water from landfills and several firing tables in the northern part of Site 300. The boundaries of the slowly moving ground water plumes lie entirely within the site boundaries. Fate and transport models predict that the tritium will decay naturally to an activity below the drinking water MCL before the tritium-bearing ground water reaches a site boundary (Webster-Scholten 1994; Taffet et al. 1996).

Maximum uranium activities that could reach potential exposure points (hypothetical ground water supply wells) at the northern boundary of Site 300 are estimated to be 0.08 Bq/L from plumes originating at Pits 5 and 7, and 0.05 Bq/L at the eastern boundary of Site 300 from the plume originating at Building 850. These conservatively estimated maximum activities are small when compared with the 0.74 Bq/L California MCL for uranium in drinking water. The predicted incremental lifetime cancer risks from the released uranium are less than one-in-a-million at the hypothetical exposure points on the Site 300 boundary (Taffet et al. 1996). The VOCs, tritium, nitrate, Freon, and depleted uranium in the shallow ground water beneath Site 300 present no current health risks, because the contaminated water is not used for potable domestic, livestock, or industrial water supplies.

9 Soil and Sediment Monitoring

Gretchen M. Gallegos

Introduction

Soil is weathered material, mainly composed of disintegrated rock and organic material, that will sustain growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. DOE guidance for environmental monitoring (U.S. Department of Energy 1991) states that soil should be sampled to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment and to estimate environmental radionuclide inventories. The guidance recommends that radionuclides specific to a particular operation or facility as well as those that occur naturally should be monitored. Particulate radionuclides are of major interest in the LLNL soil monitoring program because airborne particulate releases are the most likely pathway for LLNL-induced soil contamination.

Sediments are defined, for the purposes of this chapter, as finely divided solid materials that have settled out of a liquid stream or standing water. To evaluate current conditions, LLNL samples recent sediments in storm drainage channels and the two arroyos on site. The accumulation of radioactive materials in sediment could lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source (U.S. Department of Energy 1991). Note, however, that the LLNL Livermore site and Site 300 do not have habitats for aquatic species that are consumed by people, nor do they have surface drainage that directly feeds drinking water supplies. In addition, subsurface sediment sampling is conducted to support the LLNL Ground Water Protection Management Program (Chapter 8).

Since 1971, surface soil sampling in the vicinity of the LLNL Livermore site and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. These samples have been analyzed for plutonium and gamma-emitting radionuclides, such as depleted uranium, which is used in some explosive tests at Site 300. The inclusion of other gamma-emitting naturally occurring nuclides (^{40}K and ^{232}Th) and the long-lived fission product ^{137}Cs provides background information and baseline data on global fallout from historical aboveground nuclear weapons testing.

Similarly, sediment samples have been collected from selected arroyos and other drainage areas at and around the Livermore site since 1988; these locations largely coincide with selected storm water sampling locations (see Chapter 7). The number of sediment sampling locations was reduced in 1994 to correspond to reductions in storm water sampling locations. In addition, in 1991, LLNL began analyzing surface soil samples for beryllium, a potentially toxic metal used at both the Livermore site and Site 300. However, analysis for beryllium was discontinued at the Livermore site in 1995, because beryllium was not ever measured above background values.

Location maps for soil and sediment sampling conducted during 1997 are provided in **Figures 9-1** through **9-3**. The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as

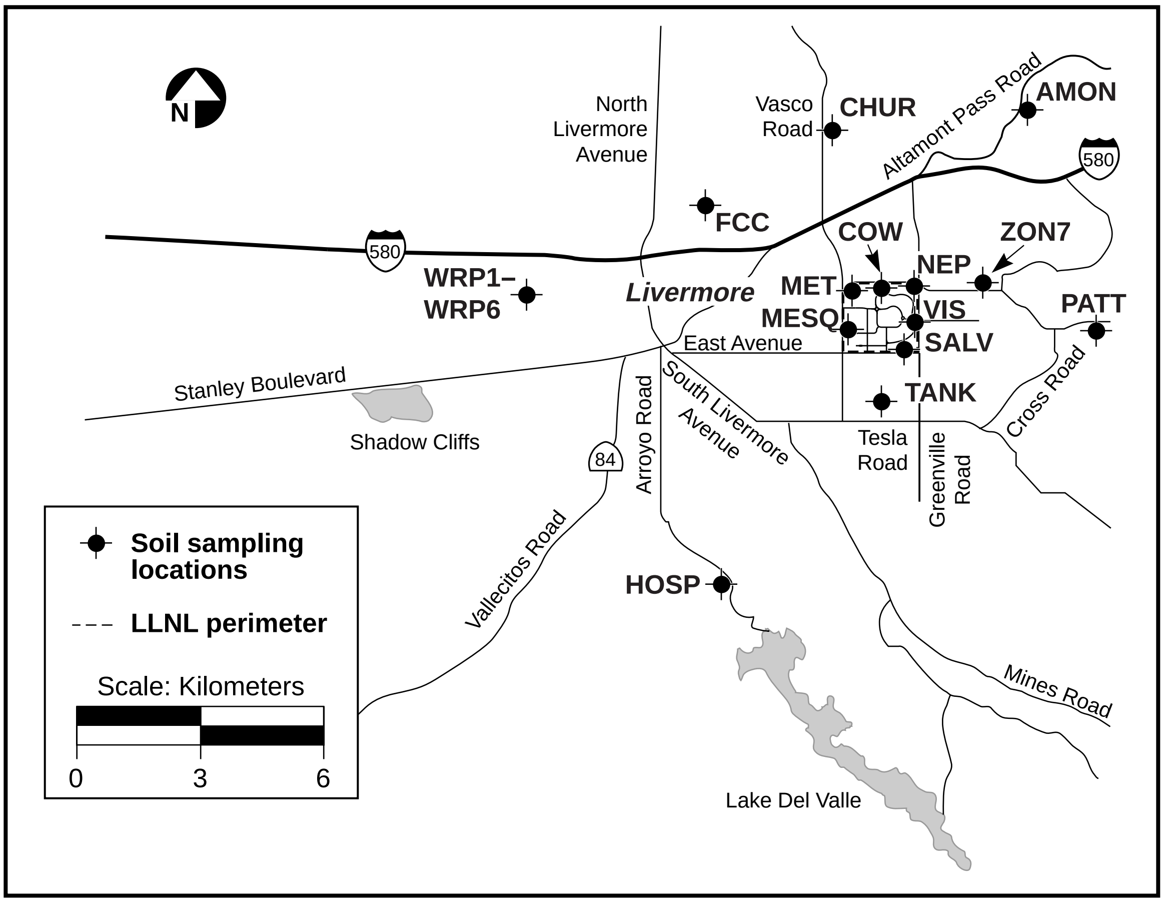

Figure 9-1. Soil sampling locations, Livermore Valley, 1997.

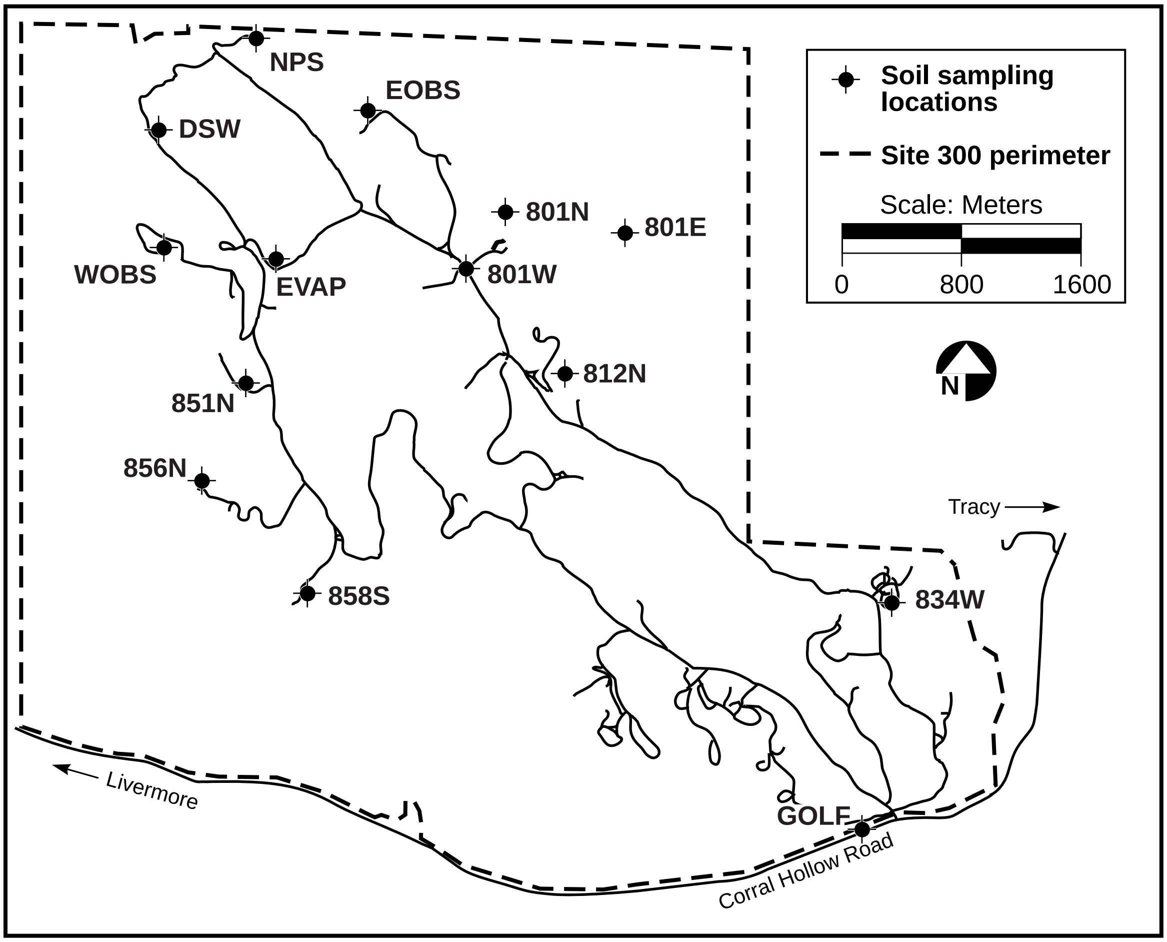

Figure 9-2. Site 300 soil sampling locations, 1997.

areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the Livermore Water Reclamation Plant (LWRP), are also sampled. In general, Site 300 soil sampling locations were established around firing tables and other areas of potential soil contamination. Arroyo and drainage channel sediment sampling locations were chosen to coincide with major Livermore site storm water drainages. All soil and sediment sampling locations have permanent location markers for reference.

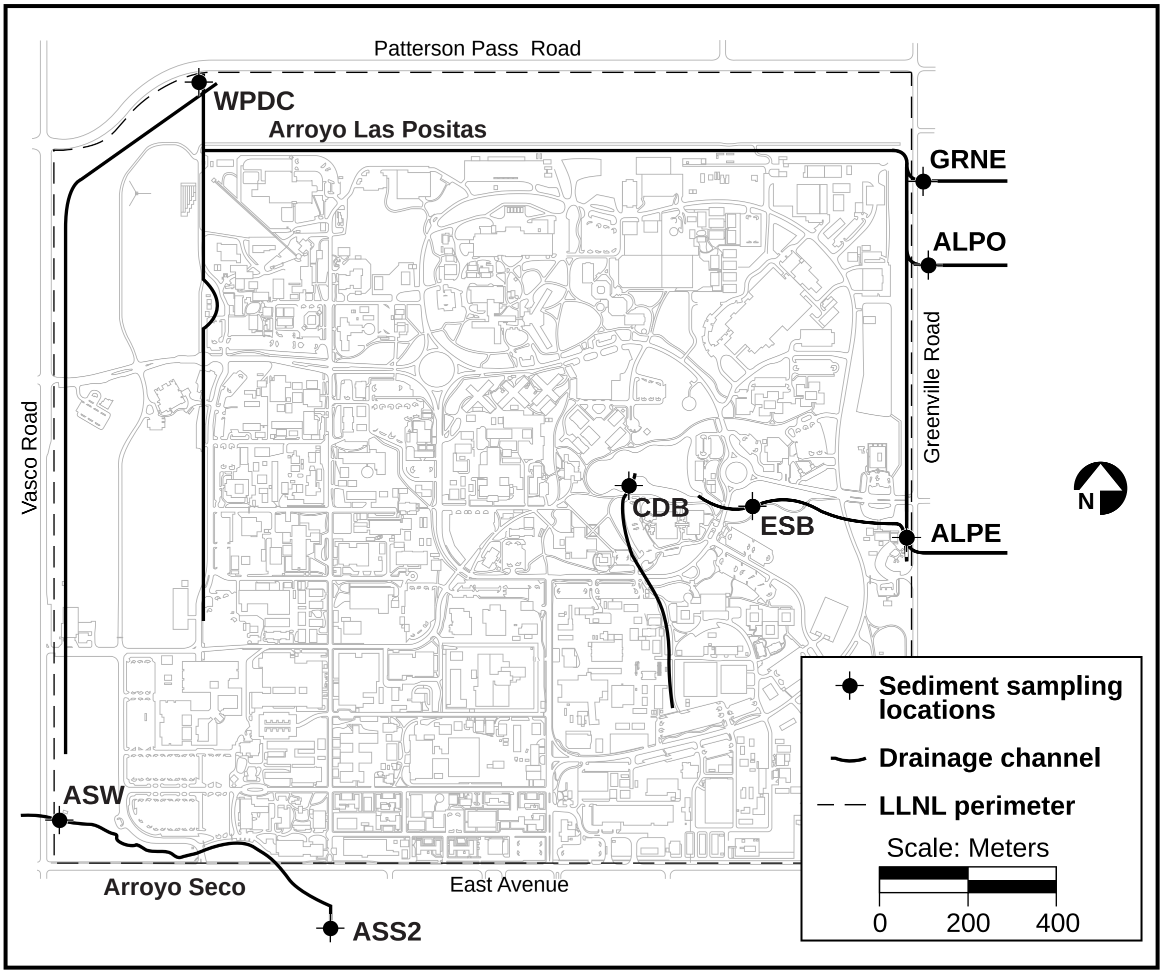

Figure 9-3. Arroyo and drainage basin sediment sampling locations, 1997.

Methods

Soil and sediment sampling is conducted according to written, standardized procedures (Tate et al. 1995). Soil samples are collected from undisturbed areas near the permanent sampling location marker. These areas generally are level, free of rocks, and are unsheltered by trees or buildings. All samples are collected from the top 5 cm of soil because surface deposition from the air is the primary pathway for potential contamination and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations.

Soil sampling location CAFE was removed from the sampling program because the location did not meet the requirement of being unsheltered by trees or buildings; it also was near a heavily travelled area. Soil sampling locations RRCH, ALTA, and ERCH were also removed from the sampling program due to problems with accessibiliy stemming from the private ownership of the property where the samples were taken. Soil sampling locations CHUR and AMON are replacement locations for RRCH and ALTA. Soil sampling location ERCH was not replaced; it was a background location, as was RRCH (which was replaced), and sufficient background samples are obtained from the other locations. Approximately 10% of samples are sampled in duplicate; two identical samples were collected at each location chosen for this sampling.

Samples of recent sediment are collected annually from drainages at and around the LLNL Livermore site after the cessation of spring runoff. Although added as a new sediment sampling location in 1997, ALPO was not sampled in 1997 because the location was constantly under water from releases upstream of the Livermore site. For 1997, samples at the Livermore site were analyzed for radionuclides, and samples for Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Analysis of Site 300 soil samples for plutonium was discontinued in 1997 because plutonium has not been used at the site and sample results have continuously been at background levels since sampling was begun in 1972. During 1997, additional subsurface sediment sampling supported the LLNL Ground Water Protection Management Program (Chapter 8).

Soil and sediment samples are delivered to LLNL's Chemistry and Materials Science Environmental Services (CES) laboratory for analyses. Soil samples are dried, ground, sieved, and blended. The plutonium content of a sample aliquot is determined by alpha spectroscopy. Other sample aliquots (300 g) are analyzed for more than 150 radionuclides by gamma spectroscopy using a high-purity germanium (HPGe) detector (Hall and Edwards 1994a, b, and c). The 10 g subsamples for beryllium analyses are sent to a contract analytical laboratory and are analyzed by graphite-furnace atomic absorption spectroscopy. For sediment samples collected for tritium analyses, CES uses freeze-drying techniques to recover water from the samples and determines the tritium content of the water by liquid-scintillation counting. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

Livermore Valley Results

Table 9-1 presents summary data on the concentrations of $^{239+240}$Pu, ^{241}Am, ^{137}Cs, ^{40}K, ^{232}Th, ^{235}U, and ^{238}U in surface soils from the Livermore Valley sampling locations. The complete data for 1997 soil and sediment sampling is presented in Table 9-1 of the Data Supplement. The concentrations and distributions of all observed radionuclides

Table 9-1. Summary of soil and sediment analytical data, 1997.

Analyte and location	Detection frequency[a]	Median	IQR[b]	Maximum
^{238}Pu (µBq/dry g)				
Livermore Valley soils	10/13	6.8	9.7	38.5
LWRP[c] soils	6/6	222	183	389
Livermore site sediments	5/7	6.4	27.8	210
$^{239+240}$Pu (µBq/dry g)				
Livermore Valley soils	13/13	64	106	559
LWRP[c] soils	6/6	4000	2577	8070
Livermore site sediments	7/7	20	364	1930
^{137}Cs (10^{-3} Bq/dry g)				
Livermore Valley soils	12/13	1.98	1.59	5.55
LWRP soils	6/6	2.33	2.29	4.14
Livermore site sediments	6/7	0.37	0.57	1.24
Site 300 soils	14/14	2.10	2.21	7.25
^{40}K (Bq/dry g)				
Livermore Valley soils	13/13	0.488	0.122	0.596
LWRP soils	6/6	0.409	0.027	0.451
Livermore site sediments	7/7	0.451	0.033	0.503
Site 300 soils	14/14	0.437	0.075	0.607
^{232}Th (µg/dry g)[d]				
Livermore Valley soils	13/13	6.9	1.3	8.1
LWRP soils	6/6	6.9	0.5	7.2
Livermore site sediments	7/7	5.2	1.4	7.7
Site 300 soils	14/14	8.8	1.9	11.9
^{235}U (µg/dry g)[e]				
Livermore Valley soils	11/13	0.020	—[f]	0.024
LWRP soils	6/6	0.019	0.004	0.025
Livermore site sediments	5/7	0.018	—[f]	0.024
Site 300 soils[g]	16/16	0.025	0.009	0.185
^{238}U (µg/dry g)[h]				
Livermore Valley soils	13/13	2.1	0.5	3.1
LWRP soils	6/6	2.1	0.2	2.8
Livermore site sediments	7/7	2.0	0.5	2.3
Site 300 soils[g]	16/16	4.1	3.5	71.3

Table 9-1. Summary of soil and sediment analytical data, 1997 (concluded).

Analyte and location	Detection frequency[(a)]	Median	IQR[(b)]	Maximum
^{3}H (Bq/L extracted water)[(i)]				
Livermore site sediments	5/7	12.5	21.7	61.1
^{241}Am (10^{-3} Bq/dry g)[(j)]				
LWRP soils	2/6	<2.6	—[(f)]	5.3
Be (mg/kg)[(k)]				
Site 300 soils	14/14	1.2	0.5	5

a Detection frequency is the number of samples with results above the detection limit/the number of samples.

b IQR = Interquartile range.

c LWRP = Livermore Water Reclamation Plant.

d Thorium-232 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 247.3, and pCi/dry g can be determined by dividing by 9.15.

e Uranium-235 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 12.5, and pCi/dry g can be determined by dividing by 0.463.

f Insufficient number of detections to calculate IQR. (See Site 300 results for discussion.)

g Includes results from reanalysis of original sample and analysis of resample.

h Uranium-238 activities in Bq/dry g can be determined by dividing the weight in µg/dry g by 80.3, and pCi/dry g can be determined by dividing by 2.97.

i Tritium (^{3}H) analysis is only conducted on sediment samples.

j Americium-241 is only detected in LWRP soil samples.

k Beryllium analysis is only conducted on soils sampled at Site 300; the analysis is a chemical, not a radiochemical analysis.

in soil for 1997 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. The ratio of ^{235}U to ^{238}U generally reflects the natural ratio of 0.7%; however, there is uncertainty in the ^{235}U/^{238}U ratio because of the difficulty in measuring small quantities of ^{238}U by gamma spectroscopy.

Plutonium has, in the past, been detected at levels above background at ZON7, the off-site soils sampling location near the LLNL Livermore site and in the prevailing downwind direction. Because of the high level of variability inherent in the measurement of soils, we do not always find plutonium above background levels at this location. As in 1991, 1994, 1995, and 1996, $^{239+240}$Pu was detected at background levels—151 µBq/g (4.1×10^{-3} pCi/g)—at location ZON7 in 1997. Since 1973, soil samples in this area have generally shown $^{239+240}$Pu values that are higher than background. The slightly higher values near the Livermore site have been attributed to historic operations, which included the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant (Silver et al. 1974). LLNL no longer operates the solar evaporators or engages in any other open-air treatment of plutonium-containing waste. Nonetheless, $^{239+240}Pu$ from historic operations is carried off site by resuspension of soil by wind. Similarly, elevated levels of $^{239+240}Pu$, resulting from an estimated 1.2×10^9 Bq (32 mCi) plutonium release to the sewer in 1967 and earlier releases, first observed in soils near LWRP during the early 1970s, again were detected at LWRP sampling locations. As in 1990 through 1992 and 1996, ^{241}Am was detected in LWRP samples; it is most likely caused by the natural decay of the trace concentrations of ^{241}Pu that were present in the release.

Historical plots of median $^{239+240}Pu$ concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site, at Site 300, and at LWRP are shown in **Figure 9-4**. Livermore Valley upwind and Site 300 concentrations have remained relatively constant since monitoring began and generally are indicative

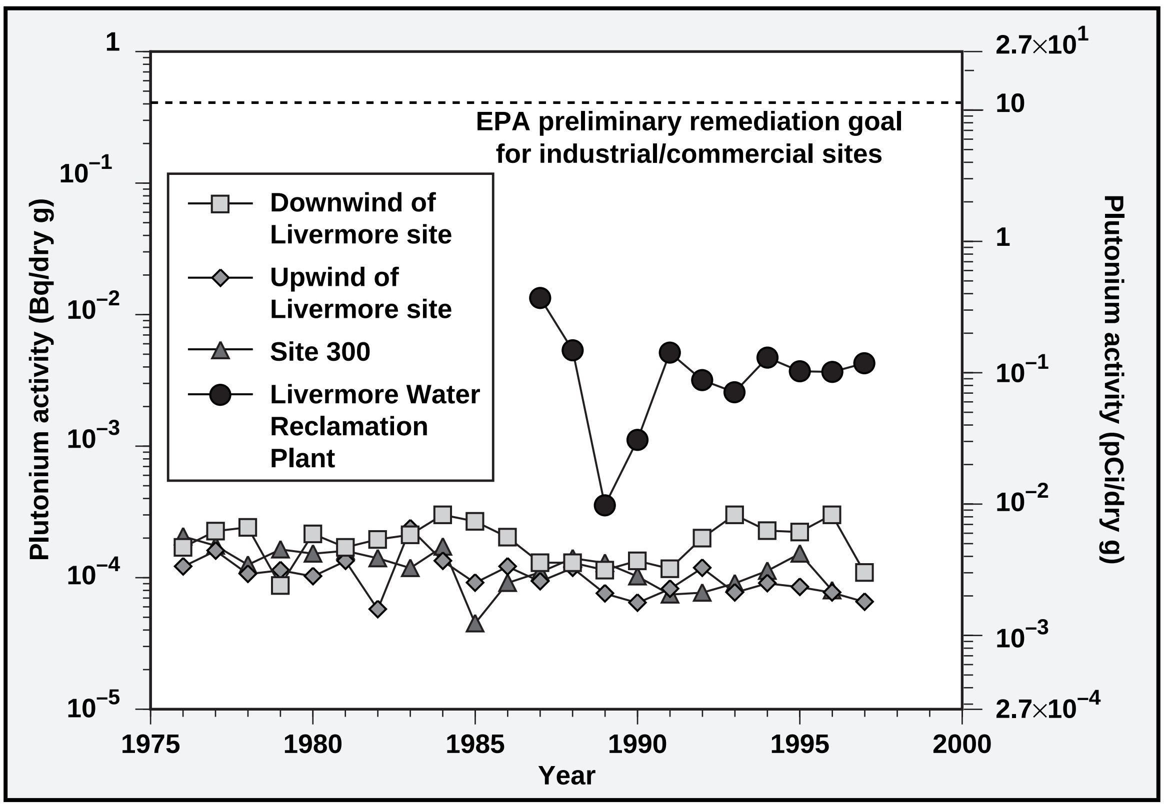

Figure 9-4. Median $^{239+240}Pu$ activities in surface soils, 1976 to 1997. Upwind and downwind designations are relative to the center of the Livermore site.

of worldwide fallout. Increased variability can be noted in the downwind concentrations, which in 1997 included sampling locations VIS, PATT, NEP, COW, and ZON7; the concentrations of plutonium at these locations reflect resuspension of low-level plutonium contamination in soils in the southeast quadrant of the Livermore site. Greater variability in $^{239+240}Pu$ is seen in samples from LWRP. However, only six samples are evaluated to determine the median at LWRP. In addition, the $^{239+240}Pu$ is likely to be present in discrete particles, so the random presence or absence of the particles will dominate the measured $^{239+240}Pu$ in any given sample.

Beryllium analysis for Livermore Valley soils was discontinued in 1995. The few LLNL operations that use beryllium are high-efficiency particulate air (HEPA) filtered. In addition, sampling data to date have shown no evidence of beryllium contamination in the Livermore Valley (Tate et al. 1995). Should beryllium usage change, LLNL's environmental monitoring staff would reevaluate the need for beryllium monitoring in soils.

Table 9-1 presents summary data on radionuclides detected in the sediment samples; a complete presentation of 1997 sediment data is found in Table 9-1 of the Data Supplement. The levels of $^{239+240}Pu$ were generally at background concentrations, reflective of worldwide fallout. The moderately higher values at sampling locations (see **Figure 9-3**) CDB and ESB may be attributed to historic activities in the southeast quadrant at LLNL; these locations are both in drainages for that area. Most other radionuclides were detected at levels similar to those reported from 1988 through 1996: ^{137}Cs, a fission product, was found at worldwide background concentrations; and ^{40}K, ^{232}Th, ^{235}U, and ^{238}U—naturally occurring radionuclides—were detected at background concentrations. Tritium concentrations were within the range of previous data. The median tritium value for 1997, 12.5 Bq/L (338 pCi/L), is slightly higher than the median tritium value for 1996, 9.5 Bq/L (257 pCi/L). This slight increase can be explained by the increase in tritium emissions from the Tritium Facility (see Chapter 4, Air Monitoring). Tritium in sediments was evaluated for differences upwind and downwind of the Livermore site. A statistically significant difference was found using the Tukey-Kramer honestly significant difference (HSD) test, with the downwind sediment samples having higher measured concentrations than the upwind sediment samples. Tritium in sediments will continue to be evaluated.

Site 300 Results

Table 9-1 presents summary data on the concentrations of $^{239+240}Pu$, ^{40}K, ^{137}Cs, ^{232}Th, ^{235}U, and ^{238}U in soil from the Site 300 sampling locations; a complete presentation of

1997 soils data for Site 300 is found in Table 9-1 of the Data Supplement. The concentrations and distributions of all observed radionuclides in Site 300 soil for 1997 lie within the ranges reported in all years since monitoring began and, with the exceptions discussed below, reflect naturally occurring concentrations. The ratio of ^{235}U to ^{238}U generally reflects the natural ratio of 0.7%. Historical trends of ^{238}U concentrations from both the Livermore Valley and Site 300 are shown in **Figure 9-5**. Median values have remained relatively constant for both places. The highest values at Site 300 result from the use in past years of depleted uranium in high-explosive tests, and are generally found at sampling location 812N. The reader may notice that the plot of maximum values differs in this report as compared to similar plots in previous reports. In previous reports, the maximum values were erroneously plotted for the years 1976, 1978, 1980, 1983, 1987, 1989, 1991, and 1992. The cause of this error has not been determined. In all cases where an incorrect data point was used, the second highest data point was plotted.

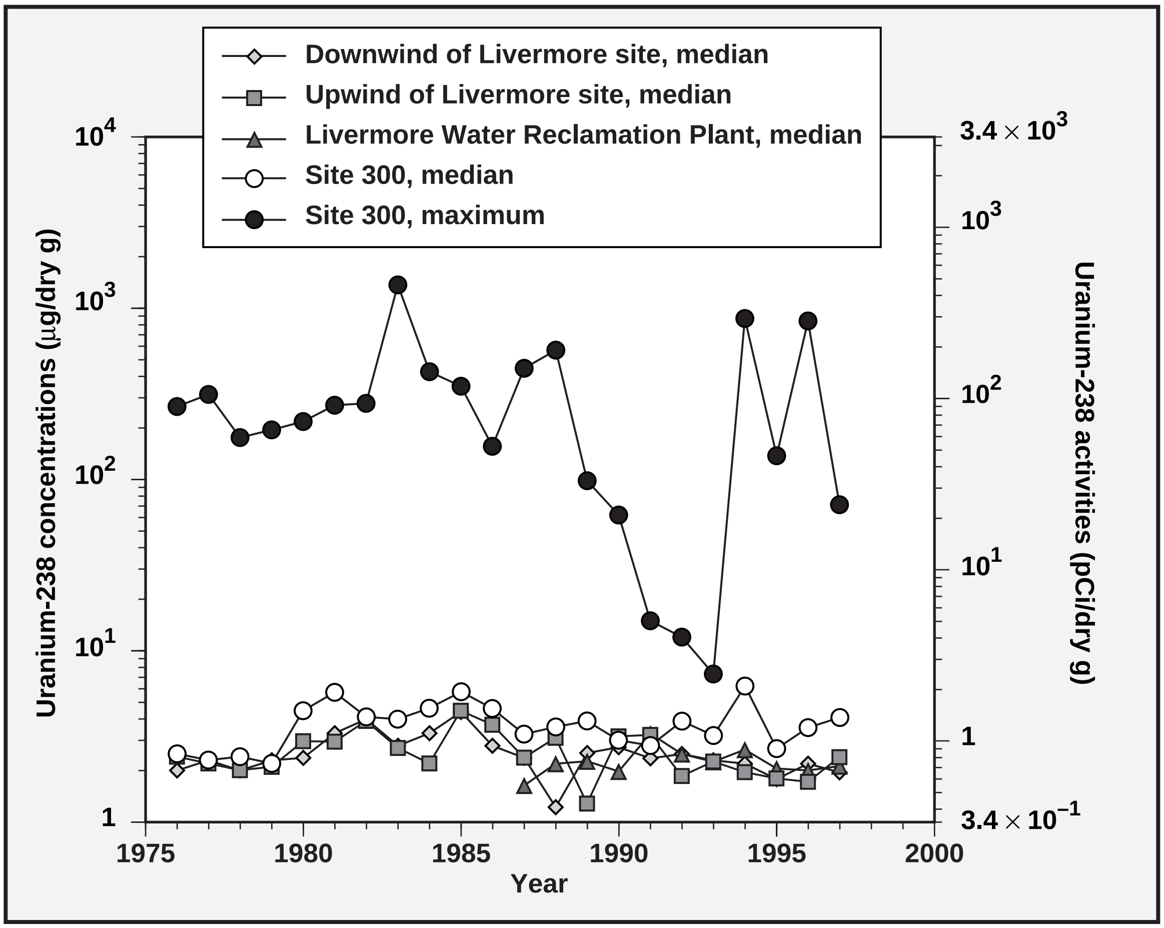

Figure 9-5. Uranium-238 concentrations in surface soils, 1976 to 1997.

During 1997, samples taken near firing tables 812N and 851N were found to contain ^{238}U at concentrations higher than background. The $^{235}U/^{238}U$ ratios in these samples were less than the ratio in naturally occurring uranium, indicating the presence of depleted uranium. Resampling and analysis of soils at 812N confirmed the presence of elevated concentrations of depleted uranium, whereas resampling and analysis of soils at the 851N did not confirm the presence of elevated concentrations of depleted uranium (see Table 9-1 in the Data Supplement). This disparity in results was not unexpected considering that the contamination is not uniformly dispersed over the soil.

Environmental Impact

This section discusses the environmental impacts at the LLNL Livermore site and Site 300 inferred from soil and sediment monitoring.

Livermore Site

Routine soil and sediment sample analyses indicate that the impact of LLNL operations on these media in 1997 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations, in trace amounts, or could not be measured above detection limits.

The highest value of 8.1 mBq/g (0.22 pCi/g) for $^{239+240}Pu$ measured at LWRP during 1997 represents 2.2% of the EPA preliminary remediation goal for commercial or industrial sites of 0.37 Bq/g (10 pCi/g) (U.S. Environmental Protection Agency 1991). Statistical analysis shows that all LWRP $^{239+240}Pu$ soils data are lognormally distributed, and at LWRP there is no general increase or decrease in $^{239+240}Pu$ values with time. Moreover, all measured concentrations, regardless of location and year, have been a small fraction of the EPA preliminary remediation goal, which is shown in **Figure 9-4** for comparison. Sampling of soils for radiological materials will continue on an annual basis.

Site 300

With the exception of elevated concentrations of ^{238}U at locations 812N and 851N, the concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are representative of background or naturally occurring levels. In 1988, contaminated gravel from the firing table at Building 812 was removed to on-site landfills; however, elevated levels of ^{238}U are still measured at this location. The investigation planned as part of the Site 300 CERCLA restoration efforts will clarify the nature and extent of the contamination in this area. The firing table at Building 851N is an active firing table, and a small fraction of the operations at the firing table disperse depleted uranium.

Big Trees Park

During the 1993 U.S. EPA investigation of plutonium in soils present in the southeast quadrant of the LLNL Livermore site, U.S. EPA personnel collected a soil sample at Big Trees Park in Livermore to obtain a background sample. This soil sample showed plutonium at a concentration higher than what is expected from global fallout for this region. The park was resampled by the U.S. EPA, LLNL, and the California Department of Health Services (DHS) in 1995.

As reported in MacQueen (1995), samples from 13 of the 16 locations sampled at the park had plutonium concentrations consistent with background levels found throughout the Bay Area. These levels were 1/600 to 1/10,000 of the U.S. EPA's risk-based preliminary remediation goal for plutonium for residential areas of 0.09 Bq/g (2.5 pCi/g) (U.S. Environmental Protection Agency 1991). Background values were found in all sandboxes, school grounds, picnic areas, and under the large eucalyptus trees for which the park is named. Samples from two locations adjacent to the ballfield had plutonium concentrations slightly above background levels, but still 1% to 2% of the U.S. EPA's risk-based preliminary remediation goal for plutonium for residential areas.

Four samples taken in the area near the original U.S. EPA sample area had plutonium concentrations that were above the initial U.S. EPA sample concentration, but even the highest concentration was 40% of the U.S. EPA's risk-based preliminary remediation goal for plutonium for residential areas. Both the U.S. EPA and the California DHS concur that there is no regulatory concern from any of the sample results, that there is no significant lifetime cancer risk resulting from the low concentrations of $^{239+240}Pu$ in the soil samples, and that there is no unacceptable risk to human health or the environment.

In 1997, the Agency for Toxic Substances Disease Registry (ATSDR), which had contracted with California DHS to conduct a health consultation for plutonium, held a public meeting on the subject of plutonium at Big Trees Park. At this meeting, the agencies restated that although the levels of plutonium at Big Trees Park were not a health concern, they were interested in knowing how the plutonium got to the park, and that this question warranted further investigation. The report issued by ATSDR on this subject was issued in draft in 1998 (see Chapter 3).

The process for obtaining additional samples to evaluate the potential pathways for plutonium to be present at the park is currently underway. It is anticipated that additional sampling will be completed in 1998. Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Table 9-2.**

Table 9-2. Special soil studies.

Year	Subject	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos et al. 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995

Vegetation and Foodstuff Monitoring

Gretchen M. Gallegos
Kris A. Surano

Introduction

Because pollutants originally released to the soil, air, or water can be transported to vegetation, DOE guidance states that periodic sampling and analysis of vegetation should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment (U.S. Department of Energy 1991). Sampling and analyzing native vegetation can provide information about the presence and movement of radionuclides in the environment. In addition, vegetation monitoring is important because plants can expose humans to radiation through direct ingestion or through ingestion of products from animals that have eaten plants that contain radionuclides.

Since 1972, vegetation and foodstuff sampling in the vicinity of LLNL and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity, to evaluate any increase in radioactivity that might have resulted from LLNL operations, and to calculate potential human doses resulting from direct and indirect ingestion of these products. During 1997, LLNL collected and analyzed samples of native vegetation and wine. Potential human doses from these foodstuffs are calculated using the monitoring data and dose models presented in Appendix B. Potential human doses from inhalation of water evaporated into the air from non-edible vegetation are determined using the EPA model, CAP88-PC.

Tritium is the nuclide of major interest in the LLNL vegetation and foodstuff monitoring program because LLNL has historically released tritium to the air both accidentally and in the course of routine operations. Tritium is likely to move into the environment as tritiated water and can be assimilated easily into vegetation and foodstuff. It can contribute to human radiation dose burdens if it is inhaled or ingested directly or indirectly. Although other radionuclides are used at LLNL, our assessments show that only tritium could be present in vegetation in detectable concentrations.

10

Vegetation and Foodstuff Monitoring

Methods

Our methods for monitoring vegetation and wine are presented in the following sections.

Vegetation

LLNL collects vegetation samples, usually annual grasses, quarterly from fixed locations in the Livermore Valley, San Joaquin County, and Site 300, and then analyzes them for tritium.

Location maps are provided in **Figures 10-1** and **10-2**. These locations have been selected so samples would represent vegetation from: (1) locations near LLNL that could be affected by LLNL operations, (2) background locations where vegetation was

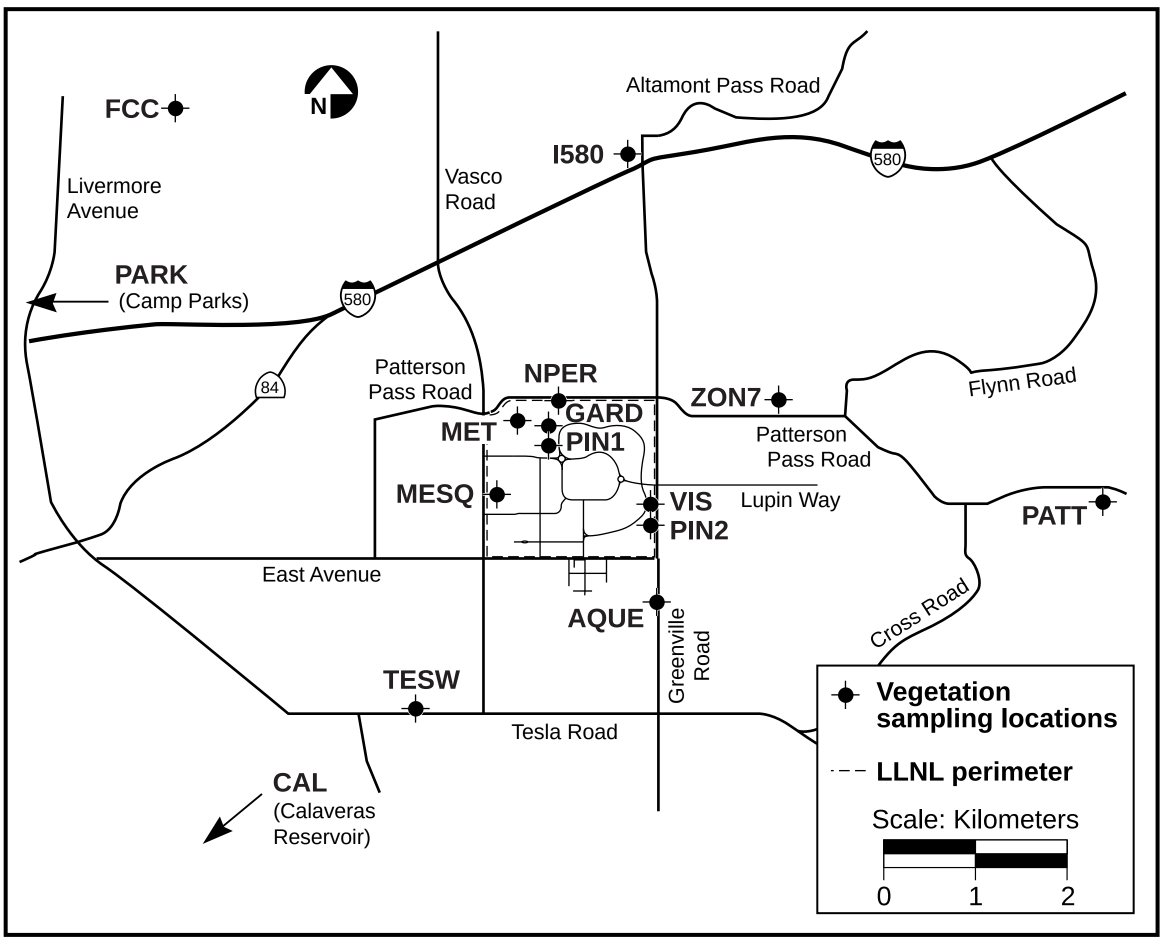

Figure 10-1. Livermore Valley vegetation sampling locations, 1997.

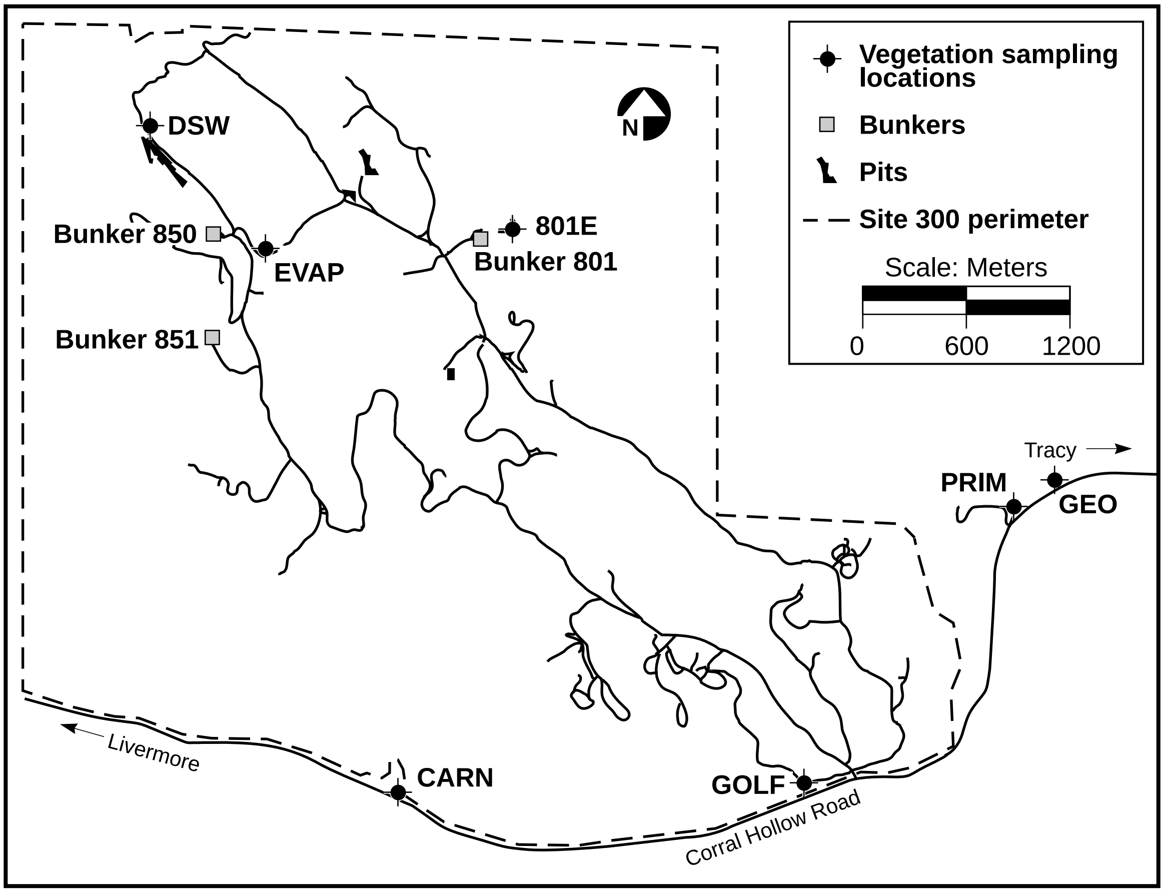

Figure 10-2. Site 300 vegetation sampling locations, 1997.

similar to that growing near LLNL but was unlikely to be affected by LLNL operations, and (3) areas of known or suspected LLNL-induced contamination. Sampling locations PIN1, PIN2, and PRIM were added in the fourth quarter of 1996. PIN1 and PIN2 were added to evaluate the emissions of tritium from a pine tree that is rooted in tritium-contaminated soil (PIN2 is a tree rooted in soil that is not contaminated with tritium). PRIM is located off site and downwind of Site 300.

All vegetation sampling is conducted according to written and approved standardized procedures (Tate et al. 1995). Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols.

Wine

Wine is the most important agricultural product in the Livermore Valley, representing an approximately $30 million annual industry. Although the tritium concentrations in all wines are low, the data since monitoring began (in 1977) indicate that Livermore Valley wines contain statistically more tritium than do their California counterparts.

Three types of wine samples were collected and analyzed for tritium concentrations: wine produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California outside the Livermore Valley, and wines produced from grapes grown in Europe (France, Germany, and Italy). The latter two groups were divided into 8 and 13 wine-producing regions, respectively, and were used as comparative samples.

The wine samples were purchased from local retailers in a variety of vintages and reflect the body of wines locally available to the general public during 1997. The resulting analytical data can be used to estimate the potential tritium dose received by consumers during the year of purchase. The 1997 sampling data cannot, however, be used to indicate how LLNL's operations affected wines produced in 1996. Some time—in some cases, several years—will have elapsed between the harvest of the grapes and the release of the vintage. However, wine sample data are decay-corrected to original tritium concentrations (given the number of months that have elapsed between wine production and LLNL analysis) to determine trends and to help determine the impact of LLNL operations during a particular vintage year.

The wine samples were submitted for analysis unopened to avoid airborne tritium contamination. Wines were analyzed for tritium using ^{3}He mass spectrometry in the LLNL Isotope Sciences Noble Gas Mass Spectrometry Laboratory (Surano et al. 1991). This highly sensitive method has a detection limit of less than 0.5 Bq/L (13 pCi/L), and is used to determine the small differences in the tritium content of the samples. Conventional scintillation detection systems typically have detection limits between 5 and 10 Bq/L (150–300 pCi/L); therefore, the differences in the samples would not have been detected had conventional detection methods been used.

Approximately 10% of the total complement of wines was sampled in duplicate, 30% of all the samples were analyzed multiple times, and traceable standards were evaluated to comply with quality assurance protocols.

Results

The results of vegetation and foodstuff monitoring for the Livermore site and Site 300 are presented below.

Livermore Site

Vegetation

Table 10-1 shows summary tritium data for vegetation collected in the Livermore site vegetation monitoring program in 1997 (the individual sampling values are presented in the Data Supplement of this report). In general, the 1997 tritium levels in vegetation were not significantly different than the levels measured in 1996.

Table 10-1. Tritium in vegetation (in Bq/L), 1997.

Location[(a)]	Detection frequency[(b)]	Median	Interquartile range	Maximum	Dose (μSv/y)[(c)]	
					Median	Maximum
Livermore site near locations	19/24	5.3	8.1	45.5	0.025	0.22
Livermore site intermediate locations	10/16	2.5	—[(d)]	9.5	0.012	0.046
Livermore site background locations	3/12	<1.3	—[(d)]	7.4	<0.006	0.035
Location DSW at Site 300[(e)]	3/5	2.6	—[(d)]	1800	0.012	8.7
Location EVAP at Site 300[(e)]	2/4	<2.9	—[(d)]	15.8	0.014	0.1
All other locations at LLNL Site 300	0/17	<1.2	—[(d)]	<1.5	<0.006	<0.007

a See **Figures 10-1** and **10-2** for sampling locations.

b Detection frequency means the fraction of samples taken having measured values above the detection limit.

c Dose calculated based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration and that meat and milk is derived from livestock fed on grasses with the same concentration of tritium. See Appendix B, Methods of Dose Calculations.

d Insufficient number of detections to calculate IQR.

e Sampling location in known area of contamination.

The Livermore Valley vegetation locations were put into four groups for statistical evaluation:

- Near—locations at or within 1 km of the Livermore site perimeter. Near locations include AQUE, NPER, GARD, MESQ, MET, and VIS.
- Intermediate—locations in the Livermore Valley further from the site (1 to 5 km from the Livermore site perimeter) but close enough and often

downwind so that they are still potentially under the influence of tritium releases at the site. The intermediate locations were I580, TESW, ZON7, and PATT.

- Far—locations unlikely to be affected by LLNL operations. One background location (CAL) is more than 25 km away. The other two (FCC and PARK) are in the Livermore Valley but are greater than 5 km from the Livermore site and are generally upwind, so they are unlikely to be affected by LLNL operations.
- Special Study—locations taken to represent a tree rooted in an area of known tritium contamination (PIN1) and a similar tree not rooted in a known area of tritium contamination (PIN2). The locations PIN1 and PIN2 were evaluated separately.

The changes in tritium levels between 1996 and 1997 for the vegetation from within each of the Near, Intermediate, and Far groups were statistically insignificant.

Because the data for tritium in vegetation were lognormally distributed, the means of the logarithms were compared, using the Tukey-Kramer honestly significant difference (HSD) test. This evaluation of the 1997 data showed a significant difference between the Near group and the other two groups; that is, the Near values are significantly different from the Intermediate and Far values, but the Intermediate values are not significantly different from the Far values. **Figure 10-3** shows the historic averages for the three groups. The highest tritium results for individual vegetation sampling locations were found at AQUE and VIS, which are located downwind of the Livermore site and historically have exhibited higher values than other locations.

In 1997, the tritium content of a pine tree growing in a known area of contamination (PIN1) was studied. Our purpose was to provide monthly data for a year, and to use the resulting data to estimate emissions from the tree for compliance with National Emissions Standards for Hazardous Air Pollutants (NESHAPs). At the completion of the year, the tree sampling was coordinated with the quarterly vegetation sampling, and subsequent NESHAPs calculations will be based on the results of quarterly sampling. To obtain a foundation for understanding the contribution of contaminated soil, a second tree that was not growing in tritium-contaminated soil (PIN2) was also sampled. Any effects of LLNL operations on the second tree would be from air deposition. **Table 10-2** provides the data for the monthly sampling of these pine trees. The results for PIN1 are higher than for any other vegetation sampling location, whereas the results for PIN2 are similar to those for the nearby location VIS, which is a routine vegetation monitoring location where annual grasses are sampled.

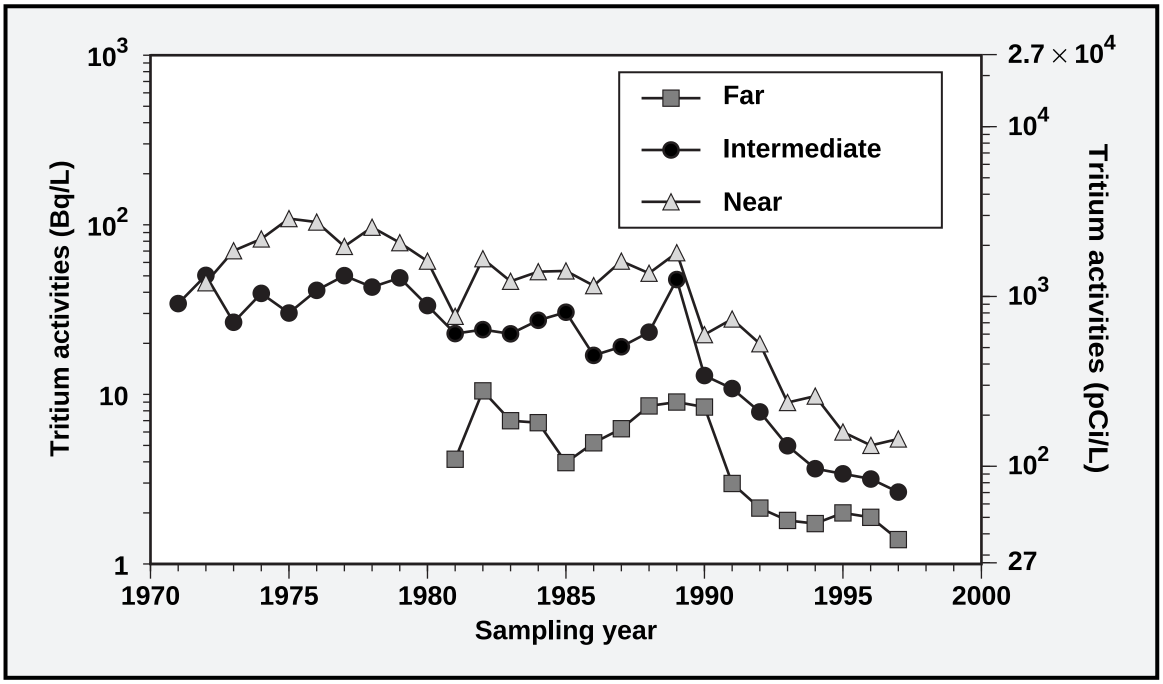

Figure 10-3. Median tritium activities in Livermore Valley vegetation samples, 1971 to 1997.

Table 10-2. Special study of tritium content (Bq/L) in a pine tree growing in a known area of contamination.

	Location	
Month	**PIN1[(a)]**	**PIN2**
January	52.9 ± 3.5	8.7 ± 2.3
February	96.6 ± 3.4	24.2 ± 2.1
March	69.6 ± 2.9	13.5 ± 1.7
April	102 ± 3	30.4 ± 2.2
May	128 ± 4	30.9 ± 2.1
June	215 ± 5	26.6 ± 2.0
July	243 ± 5	15.6 ± 1.7
August	274 ± 6	12.5 ± 1.9
September	326 ± 6	17.8 ± 1.8
October	221 ± 4	15.2 ± 1.4
November	215 ± 5	13.4 ± 1.6
December	67.3 ± 2.8	5.7 ± 1.3
Median	**172**	**15.4**
Maximum	**326**	**30.9**
Maximum Dose	**1.7×10^{-5} µSv (1.70×10^{-6} mrem)**	**1.6×10^{-6} µSv (1.6×10^{-7} mrem)**

a Sampling location in area of known contamination.

Wine

The results from the 1997 wine tritium analyses are shown in **Table 10-3**. Tritium concentrations were within the range of those reported in previous years, and they remained low in wines from all areas.

Table 10-3. Tritium (Bq/L) in retail wine, 1997.[a]

Region	Detection frequency	Median	Interquartile range	Mean	Maximum	Dose[b] µSv/y (mrem/y)
Livermore Valley	12/12	2.45	1.64	2.89	7.96	0.0026 (0.00026)
California	6/6	0.47	0.19	0.51	0.75	0.0005 (0.00005)
Europe	4/4	1.61	0.75	1.91	3.29	0.0017 (0.00017)

a Wines from a variety of vintages were purchased and analyzed during 1997. The concentrations shown are not decay-corrected to vintage year.

b This dose is calculated from conservative assumption of drinking 52 L wine/year and using the mean concentration of sampled wines.

The data for the 1997 sampling year were analyzed using analysis of variance (ANOVA). The statistical analyses showed that the mean tritium concentration of the Livermore wines sampled was statistically greater than that of the California (other than Livermore) wines. The statistical analyses also indicated that there was no significant difference between the mean tritium values of the European and California wines sampled or between the Livermore and European wines. Multiple comparison tests indicated that the mean levels of the 1997 sampling year data from all areas were not significantly different from those reported for the 1995 and 1996 sampling years. **Figure 10-4**, which shows the results of the wine analyses by sampling year since monitoring began, also shows that 1997 tritium concentrations are among the lowest for all reported Livermore wines.

During the review of historical data in 1995, it was discovered that the data being reported for the 1977 and 1979 sampling years were averages across multiple sampling years. These data have been corrected in **Figure 10-4**, and are the reason for differences observed when comparing this figure to those published before 1995.

Regression analyses and ANOVA of the wine data when decay-corrected and grouped by vintage year (1996 is the last sampled vintage) showed tritium concentrations have statistically decreased for all regions since 1984 (see **Figure 10-5**). Livermore wines, examined by vintage year, show statistically greater tritium concentrations for the period 1986 through 1996 than both European and California wines. Nevertheless, it is important to note the continued downward trend in the tritium concentrations of

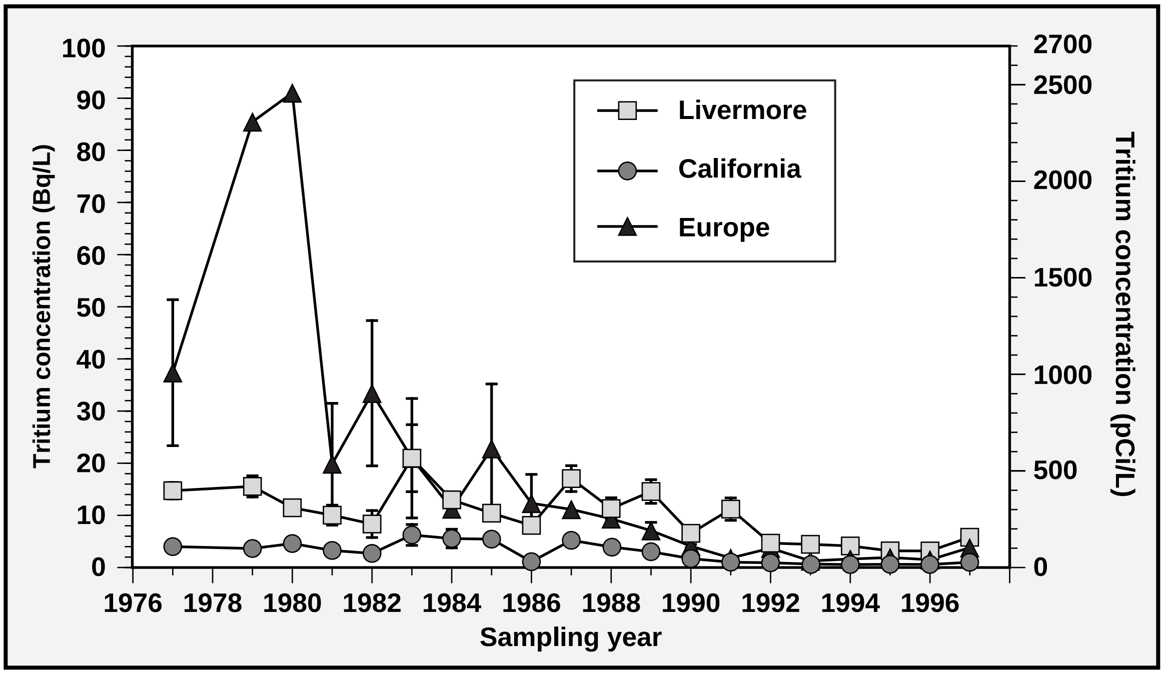

Figure 10-4. Mean tritium in retail wines, 1977 to 1997, plotted by sampling year (error bars are ±1 standard error).

Livermore wines (when decay-corrected and grouped by vintage year) that has been observed since 1984 (when tritium operations at LLNL were scaled down and total amounts of tritium released were reduced).

Site 300

Vegetation

Table 10-1 shows summary tritium data for vegetation collected at Site 300 during 1997. Historic values for tritium at Site 300 sampling locations are shown in **Figure 10-6**. Of the six sampling locations at Site 300, four yielded results at or near the detection limits. Two locations, EVAP and DSW, yielded results above background.

The highest tritium result for a single vegetation sample occurred at the location DSW (see **Table 10-1**). The sample was not the usual native annual grass, but a thorn apple bush (*Datura wrightii*), which, like the stinging nettle (*Urtica dioica)* that in 1996 yielded a high tritium measurement, has a relatively long tap root. The thorn apple bush was

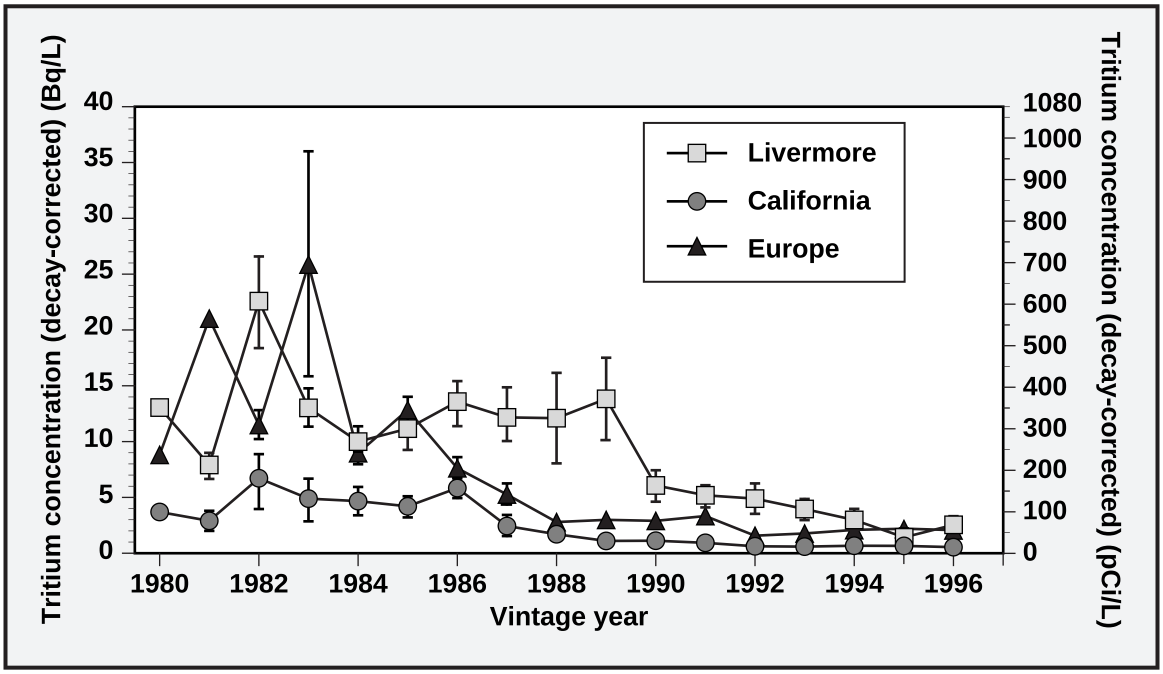

Figure 10-5. Mean tritium in retail wines, vintages 1980 to 1996 values are decay-corrected and plotted by vintage year (error bars are ±1 standard error).

chosen for sampling because it was the only living (i.e., green-colored) vegetation in the area of the sampling location during the summer; its long tap root was evidenced by the plant's greenery, which contrasted dramatically with the brown of the annual grasses.

Tritium has been observed in the vegetation of the DSW sampling location since 1971; it is in an area presently being investigated under CERCLA for tritium contamination of ground water. This sampling location is adjacent to a landfill that contains debris contaminated with tritium from past experiments. The landfill area is under continued investigation for tritium in soil and ground water, as described in reports published as part of LLNL's Environmental Restoration Program (Lamarre 1989a, b, and c; Taffet et al. 1989a and b; Taffet et al. 1991; Carlsen 1991a and b; and Webster-Scholten 1994). The tritium results in vegetation samples that were above background values also occurred at the location EVAP. The location EVAP is near a spring where ground water flows near the surface and evaporates. The ground water in this area is contaminated with tritium which comes from three sources, Pit 3, Pit 5, and the firing table at Building 850 (see discussion of Wells NC7-61 and NC7-69 in Chapter 8, Ground Water). Evaluation of the 1997 data for Site 300 using the Tukey-Kramer HSD test on the logarithms of the data yielded no significant differences among the various sampling locations; this is a result of the high variability of the data and the low number of data points. However, if the 1995 and the 1996 data are combined with the 1997 data, a

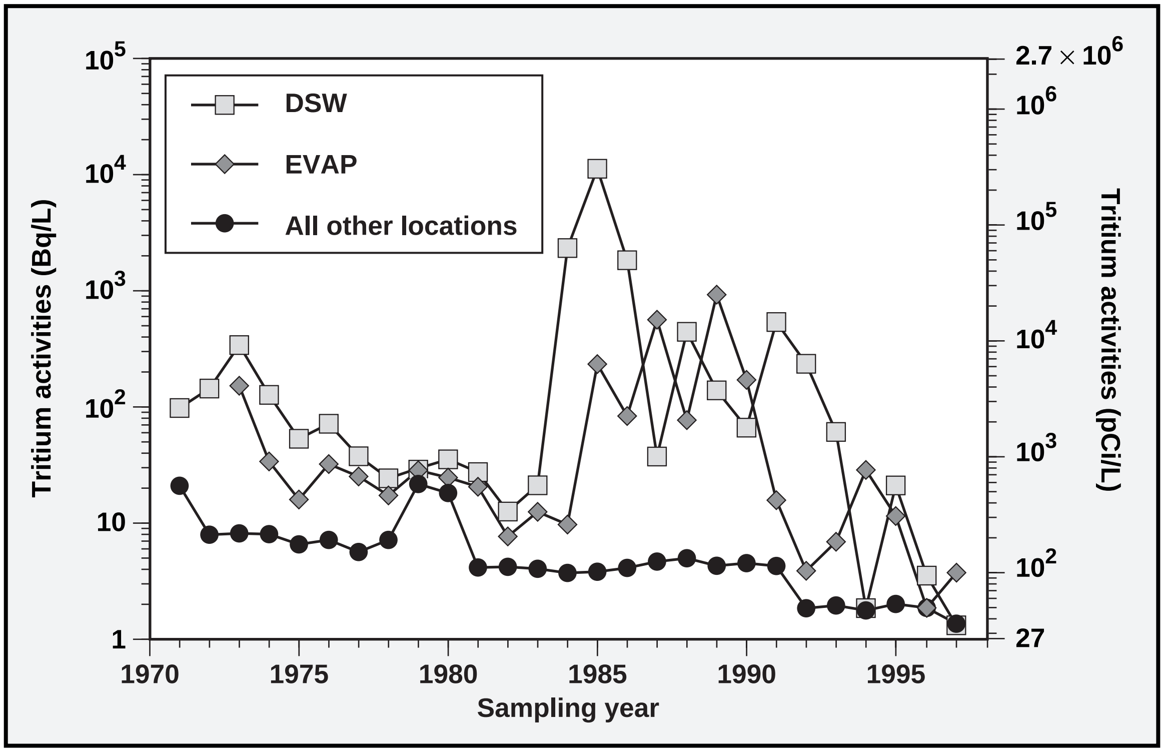

Figure 10-6. Median tritium activities in vegetation at Site 300 sampling locations, 1971 to 1997.

significant difference is found between the set of locations comprising GEO, CARN, GOLF, and 801E, and locations DSW and EVAP. This is a result of the fact that DSW and EVAP are located in areas of known tritium contamination.

Environmental Impact

The environmental impacts of LLNL operations on vegetation and foodstuff monitoring are small and are presented below for the Livermore site and Site 300.

Livermore Site

LLNL impacts on vegetation in the Livermore Valley remained minimal in 1997. The effective dose equivalents shown in **Table 10-1** were derived using the dose conversion factors provided by DOE (U.S. Department of Energy 1988) and the dose pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977).

Appendix B provides a detailed discussion of dose calculation methods. The dose from tritium in vegetation is based on the conservative assumptions that an adult's diet consists exclusively of vegetables with the measured tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration. These assumptions are conservative because most vegetables consumed directly by an adult will not contain tritium at the levels reported (the tritium levels will actually be much lower), nor will the livestock actually consume vegetation with the reported levels of tritium. Based on these conservative assumptions, the maximum potential dose (from ingestion of affected vegetation) for 1997 for the Livermore site is 0.46 μSv (0.046 mrem). The contribution of any organically bound tritium (OBT) is not included in these calculations; they are based only on the tritium in the water fraction of the plant. A conservative estimate of such a contribution would be to assume that the entire plant is organic matter (the actual fraction of plants that is organic matter varies from plant to plant and also varies among the tissues of the plant), that is—all the calculated dose is from OBT—and use that assumption to calculate a upper-bound estimate of the dose from vegetation. Using the ratio of the dose conversion factors of OBT (4.2×10^{-11} Sv/Bq) and water fraction tritium (1.8×10^{-11} Sv/Bq) from International Commission on Radiological Protection Publication 67 (ICRP 1994) of 2.33 to make such an estimate, the maximum potential dose (from ingestion of affected vegetation) for 1997 for the Livermore site would be 1.07 μSv (0.107 mrem), a dose well below any level of concern.

The dose values shown in **Table 10-2** are calculated in a different manner than those for annual vegetation because it is unreasonable to assume that any person or animal is directly ingesting a pine tree. The dose estimates for the pine trees are based on estimates of transpiration of tritium from the trees into the atmosphere; these estimates are used as input data to the U.S. EPA regulatory model CAP88-PC, which models the air dispersion of the transpired tritium and calculates a resulting dose. These doses are also based on the conservative assumptions that an adult's diet consists exclusively of vegetables with the measured tritium concentration, and meat derived from livestock fed on grasses with the same concentration. The resulting dose for PIN1 of 1.7×10^{-5} μSv (1.7×10^{-6} mrem) is considerably lower than the other calculated vegetation doses because the trees are not directly ingested, rather the dose is calculated based on the subsequent deposition of tritium evapotranspirated from the tree.

No health standards exist for radionuclides in wine. However, all the wine tritium levels were far below drinking water standards. In fact, even the highest detected Livermore Valley value (7.96 Bq/L or 215 pCi/L) represents only 1.1% of the California drinking water standard (740 Bq/L or 20,000 pCi/L). Doses from wine consumption can be calculated according to methods for water ingestion, which are detailed in Appendix B.

The annual dose that corresponds to the highest detected 1997 Livermore Valley tritium value in wine (7.96 Bq/L [215 pCi/L]) is 0.099 µSv (0.0099 mrem), based on the extremely conservative assumption that wine is consumed in the same quantities as water (730 L/year or 2 L/day). Using a more realistic wine consumption factor (52 L/year or 1 L/week of wine from a single area) and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.0026 µSv (0.00026 mrem), from European wine would be 0.0017 µSv (0.00017 mrem), and from California wine would be 0.0005 µSv (0.00006 mrem). Compared with an annual background dose of approximately 3000 µSv (300 mrem), which includes radon, and a 100-µSv (10-mrem) dose from a typical chest x-ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Therefore, although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

Site 300

In general, LLNL impacts on vegetation at Site 300 for 1997 were insignificant. Tritium levels found in the Site 300 vegetation were comparable to those observed in previous years. With the exception of vegetation from previously identified sites of contamination, the levels were low, near the limits of detection. The areas where tritium is known to be present in the subsurface soil are well delineated and localized.

The calculated maximum potential annual dose from vegetation at sampling location DSW, based on the maximum value of 1800 Bq/L (48700 pCi/L), is 8.7 µSv (0.87 mrem). This dose, which would never actually be received by anyone, is about 11.5 times less than a chest x-ray (Shleien and Terpilak 1984). This calculation uses the same conservative pathway modeling assumptions, as described above. In actuality, this dose never would be received because vegetation at Site 300 is not consumed by people or by grazing livestock. In comparison, the calculated potential annual dose from vegetation at all other locations at Site 300 had a median value of <0.006 µSv (<0.0006 mrem; the value is a “less than” value because all measured tritium levels were less than the detection limit). Tritium levels in vegetation at Site 300 will continue to be monitored.

11

Environmental Radiation Monitoring

Barbara C. Fields

Introduction

A variety of radioisotopes are used at LLNL for biomedical, general, and nuclear weapons research. These include transuranics, tritium, and mixed fission products. In accordance with federal regulations, DOE Orders 5400.1 and 5400.5, and Title 17, California Code of Regulations, Section 30250, LLNL monitors direct gamma radiation to establish background radiation levels in its vicinity and to determine the direct environmental radiological impact of its operations. Gamma radiation results from natural background sources of terrestrial or cosmic origin and from man-made sources, such as fallout from past nuclear weapons testing and any contribution from LLNL operations.

Because environmental radiological monitoring is used as one measure of the potential direct radiation dose the public receives as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for the Livermore site perimeter, the Livermore Valley, and the Site 300 perimeter. Direct gamma radiation has been measured at the Livermore site since 1973, and a direct environmental radiation monitoring program was implemented at Site 300 in 1988. Direct gamma radiation is measured using thermoluminescent dosimeters (TLDs), which provide a measure of the total amount of gamma radiation at a particular location. Environmental neutron monitoring, which was also started in 1973, was discontinued at the end of 1994. Currently, environmental exposure to neutrons is not a concern at LLNL. However, should it become necessary for LLNL to start up operations that produce neutrons at significant levels, environmental neutron monitoring can be resumed. As a result of a gamma network assessment, the number of monitoring locations was reduced in 1995 (Harrach et al. 1996).

Monitoring Locations

External doses from direct gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 11-1**), and 23 Livermore Valley locations (**Figure 11-2**) in 1997. These off-site locations are used for background comparison with perimeter locations. Similarly, gamma doses were monitored at nine perimeter monitoring locations at Site 300 (**Figure 11-3**), five in areas near Site 300, and two locations in nearby Tracy. Six monitoring locations near Site 300 were added as part of a special study in 1993. Monitoring has continued at these locations to provide data from areas not likely to be affected by LLNL operations. Sampling at locations 84 and 95 was discontinued in 1996.

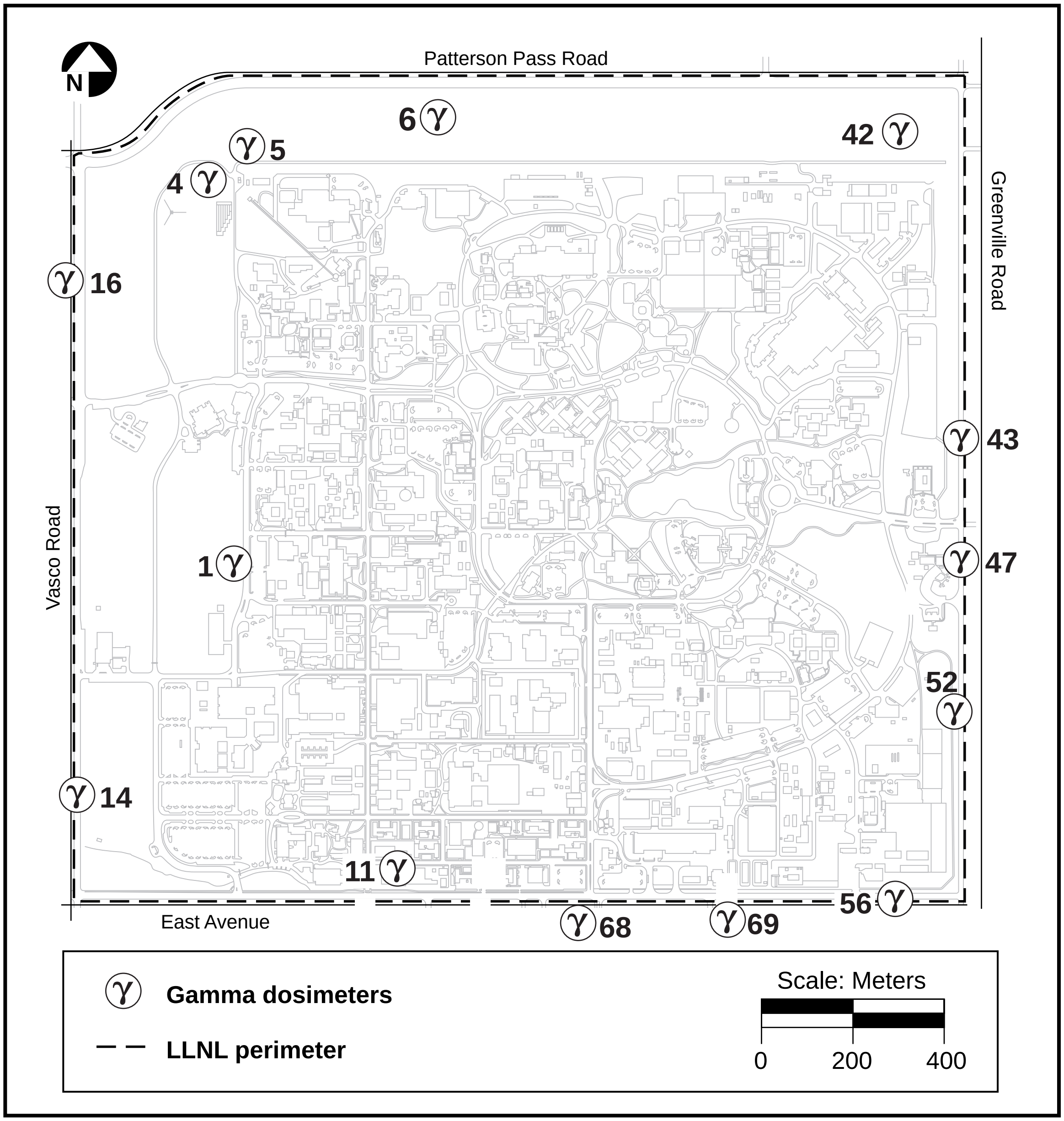

Figure 11-1. Gamma dosimeter locations, Livermore site, 1997.

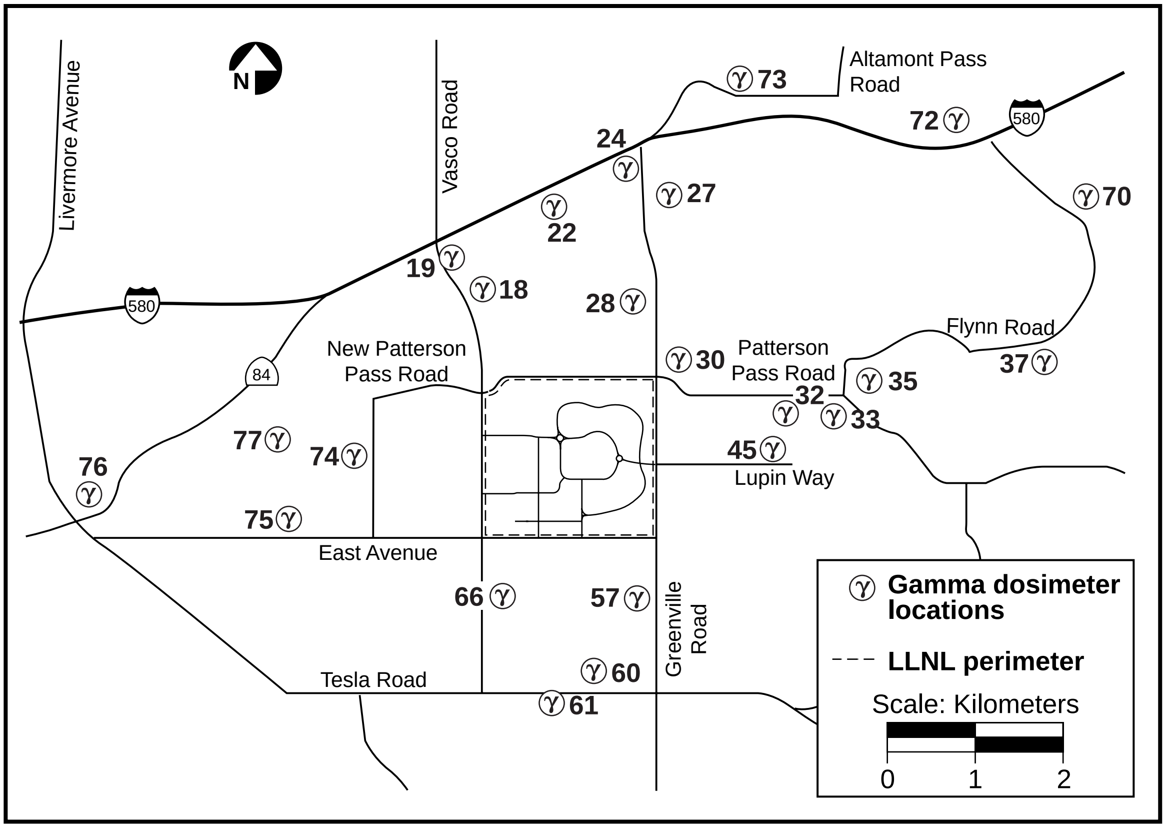

Figure 11-2. Gamma dosimeter locations, Livermore Valley, 1997.

Results of Gamma Monitoring

In 1995, all of the quarterly gamma radiation data points were normalized to standard 90-day quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). This practice was continued in the 1997 data processing and analyses. By using the same standard-quarter reporting method, data from other DOE and NRC facilities and data from intercomparison studies can be more easily compared. As shown in **Figure 11-4**, when our data are adjusted to standard quarters, the variability in exposures that was previously reported in 1995 is reduced.

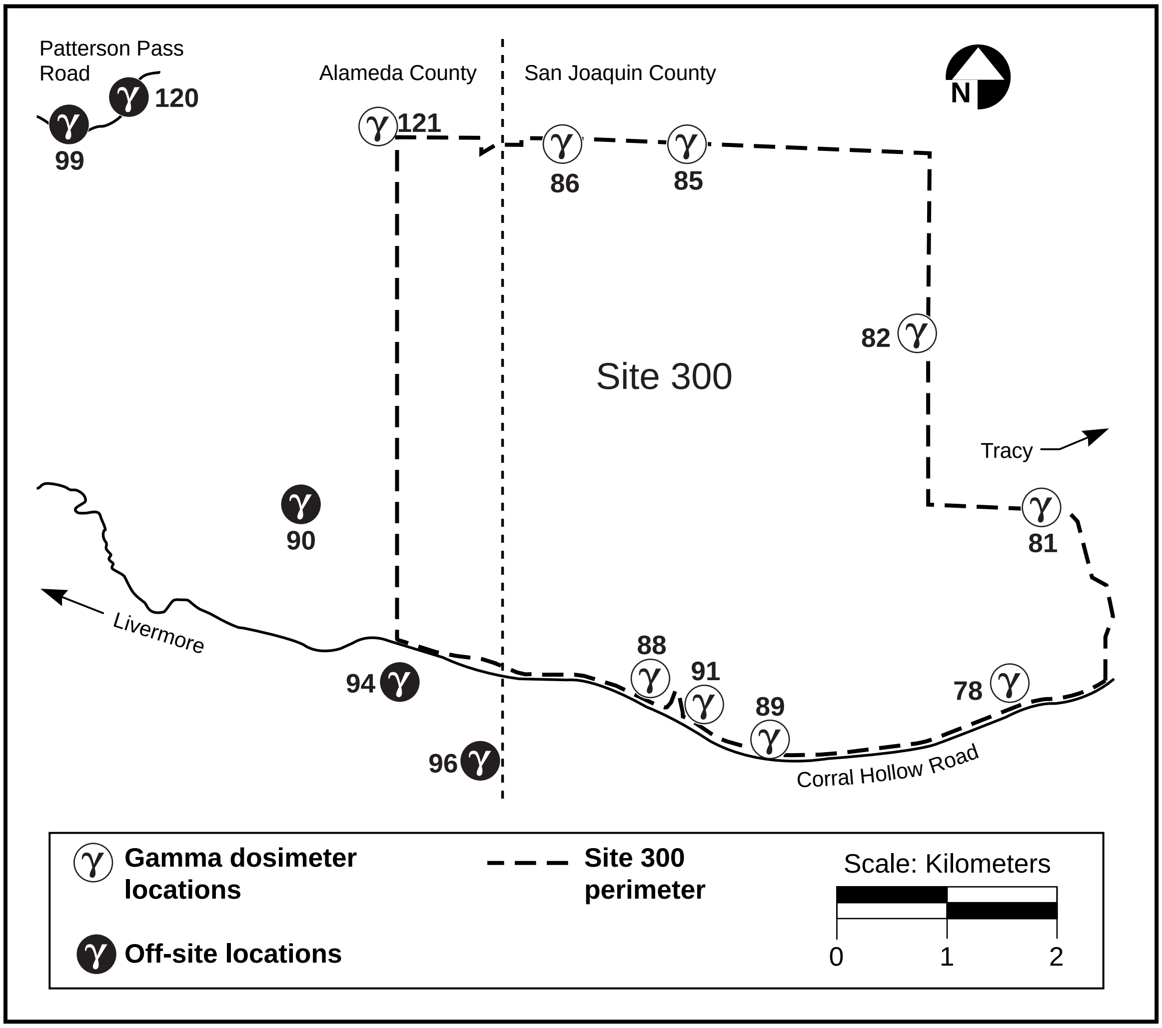

Figure 11-3. Gamma dosimeter locations, Site 300 and vicinity, 1997.

Livermore Site

Table 11-1 presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore site perimeter locations and Livermore Valley off-site locations. The mean 1997 dose equivalent from external direct radiation exposure at the Livermore site perimeter, 0.59 mSv (59 mrem), is statistically the same as background external dose measured in the Livermore Valley, 0.60 mSv (60 mrem). **Table 11-2** lists the yearly doses due to direct gamma radiation at the LLNL site perimeter. All doses fall within the predicted range for background radiation, and no LLNL operational impacts are discernible.

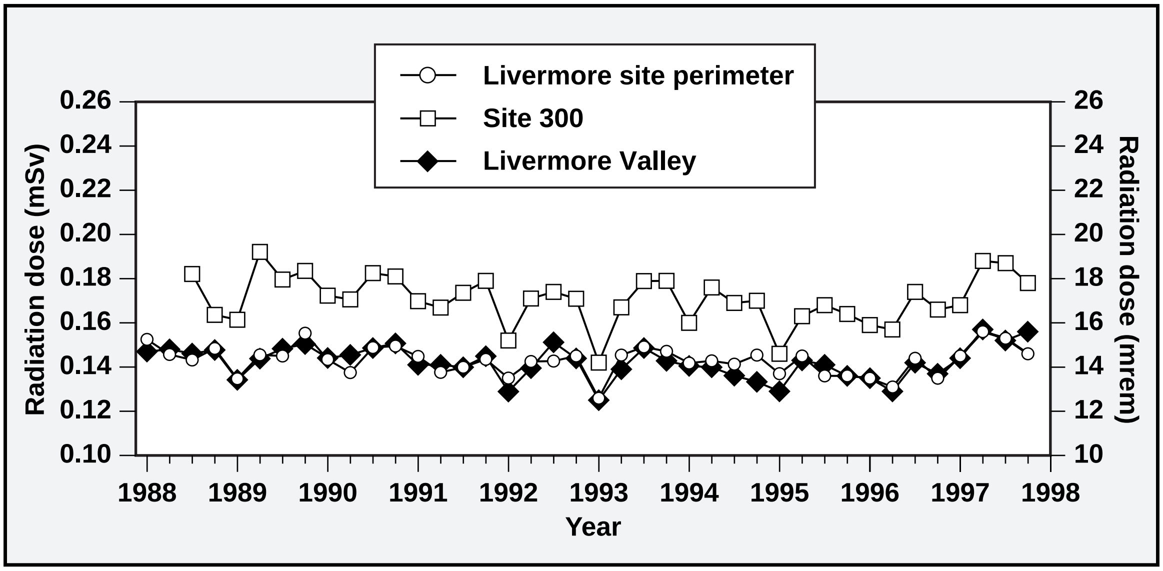

Figure 11-4. Gamma measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988 to 1997.

Site 300

As seen in **Table 11-1**, the measured Site 300 perimeter average dose in 1997 was 0.72 mSv (72 mrem), the measured dose at the off-site locations near Site 300 was 0.77 mSv (77 mrem), and the measured doses in and near Tracy were 0.62 mSv (62 mrem). All doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

At Site 300, the initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the city of Tracy, which were chosen to represent background radiation levels. However, the Tracy locations are located on a geological substrate different from that at Site 300. The region around Site 300 has higher levels of naturally occurring uranium, which is present in the Neroly Formation. The mean dose measured in the off-site locations of the area around Site 300, which is used to represent the high end of background radiation from this formation, was 0.77 mSv (77 mrem) and is greater than the Site 300 perimeter dose of 0.72 mSv (72 mrem). The Tracy area, with a dose of 0.62 mSv (62 mrem), is at a lower elevation, with geological constituents composed of alluvial deposits of clays, sands, and silts overlying the bedrock. The difference in doses can be directly attributed to the difference in geologic substrates.

Table 11-1. Summary of dose calculations for gamma monitoring locations at all sites in 1997 (in mSv).[a]

Quarter	Location									
	Livermore site		Livermore Valley		Site 300		Tracy		Other off site	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
First	0.145	0.012	0.144	0.014	0.168	0.016	0.148	0.018	0.183	0.026
Second	0.156	0.013	0.157	0.016	0.188	0.018	0.161	0.018	0.210	0.028
Third	0.153	0.013	0.152	0.016	0.187	0.019	0.162	0.012	0.200	0.028
Fourth	0.146	0.011	0.156	0.013	0.178	0.014	0.151	0.013	0.189	0.029
Total[b]	**0.601**		**0.599**		**0.722**		**0.621**		**0.772**	

a 1 mSv = 100 mrem.

b The total represents annual totals given in the Data Supplement, which accounts for missing data by averaging data given for each site.

Table 11-2. Annual dose by year at the Livermore site perimeter due to direct gamma radiation.[a]

Year	mSv	mrem
1988	0.59	59
1989	0.58	58
1990	0.58	58
1991	0.56	56
1992	0.56	56
1993	0.57	57
1994	0.56	56
1995	0.56	56
1996	0.55	55
1997	0.59	59

a Data normalized to standard 90-day quarters (360-day years).

The adjusted doses at the Livermore site perimeter and in the Livermore Valley are comparable and lack significant trend from 1988 to 1997. However, while Site 300 doses are similarly without trend, they continue to measure slightly higher direct gamma doses than the Livermore site and the Livermore Valley, which is expected given the differences in geology between these sites.

In reviewing the trends of the standard quarter data as shown in **Figure 11-4**, it appears that seasonal variation can occur during the rainy season, most likely because of a decrease in radon emanation from the moist soil. As shown in the figure, the variation was absent during the severe drought years in Northern California (1990/1992) but is apparent when rainfall returned to normal (1994/1995) and above-normal levels (1993).

Environmental Impact

Based on past measurements (Lindeken et al. 1973), environmental terrestrial (geologic) radiation doses in the Livermore Valley vary from 0.25 to 0.60 mSv/y (25 to 60 mrem/y). Cosmic radiation, as calculated for the local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966), is about 0.35 mSv/y (35 mrem/y). This combination results in a typical total direct radiation dose level of 0.60 to 0.70 mSv/y (60 to 70 mrem/y); however, local geological and meteorological factors will impact these dose levels. Direct radiation doses measured at the Livermore site perimeter in 1997 are near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. This indicates that any dose from LLNL operations is not large enough to be seen within the wide range of natural variation in background levels in different locations.

12

Radiological Dose Assessment

Robert J. Harrach

Introduction

Radiological doses to the public result from both natural and man-made radiation. The total dose to different populations can be determined by measurements and calculations. This chapter describes LLNL's radiological dose assessments, made to determine the impact of LLNL operations, and contains a discussion of the analyses we performed to demonstrate LLNL's compliance with the radiological National Emission Standards for Hazardous Air Pollutants (NESHAPs; 40 CFR 61 Subpart H).

Background Information

Because this report has a diverse readership, a brief tutorial on radiation is included at the end of the chapter to enable the nonspecialist to understand more easily the radiological dose assessment information. The tutorial, Supplement 12-1: "Radiation Basics," describes the different sources and types of radiation and the units used to quantify it, and provides some perspective on the wide range of radiation levels people commonly encounter. One additional supplement provides ancillary information: Supplement 12-2 describes LLNL's standard operating procedures that protect employees and the public from uncontrolled releases and unsafe levels of radiation. Readers can bypass all discussion of concepts, methods, and tools by proceeding directly to the section on "Radiological Doses from 1997 Operations."

Releases of Radioactivity to Air

Air releases are by far the major source of radiological exposures of the public from LLNL operations. In contrast, releases to water (sewerable, ground, and surface waters) are not sources of direct public exposures, since these waters are not directly consumed or used by the public. Water releases can cause indirect exposures, which are then treated as special cases; for example, inhalation or ingestion of soil contaminated by sewer effluent containing radioactivity. Apart from such unusual occurrences, measurements and modeling of air releases determine LLNL's radiological dose to the public.

Data are gathered by three principal means: routine surveillance air monitoring for radioactive particulates and gases, both on and off Laboratory property (described in Chapter 5); continuous monitoring of stack effluent at selected facilities at the Livermore site (described in Chapter 4); and usage inventories at all non-continuously monitored or unmonitored facilities housing radioactive materials management areas and for radioactive materials used in explosive experiments at Site 300 (described in LLNL's NESHAPs annual reports [e.g., Gallegos et al. 1998]).

Despite this "air emphasis," it should be noted that LLNL's extensive environmental monitoring program embraces all media and a wide range of potential contaminants, not limited to radioactive ones. Monitoring has been covered extensively since 1971 in LLNL's Environmental Reports (e.g., Harrach et al. 1997) (see Chapters 4 through 11 in the present report) and in LLNL's triennially updated *Environmental Monitoring Plan* report (e.g., Tate et al. 1995) and its associated Procedures and Guidance Documents. In addition to air and the three categories of water already mentioned, the Laboratory samples soil, sediment, vegetation, and foodstuff, and measures environmental (gamma) radiation. Concentrations of nonradioactive toxic and hazardous materials as well as radioactive materials in all of these media are reported annually in the *Environmental Report*.

Air Dispersion and Dose Models

Calculational models are needed to describe the transport and dispersion in air of contaminants and the doses experienced by exposed populations. Various factors dictate this need for modeling: (1) the amounts of LLNL-generated radioactive material dispersed into the atmosphere cause doses thousands of times smaller than those caused by natural background radiation (arising from irradiation by cosmic rays, inhalation of radon gas, exposure to radioactive materials in soil and rock, and ingestion of naturally occurring radionuclides present in our food and water), so it is difficult to demonstrate compliance with standards through physical measurements alone; (2) all significant exposure pathways need to be taken into account when estimating dose impacts, entailing the use of a good dosimetry model; and (3) the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) sanction the use of specific computer codes that implement their approved dosimetry and dispersion models, and mandate that these codes be used to calculate potential doses to the public from exposures resulting from both routine and unplanned releases. Other advantages of a well-developed modeling capability include its utility in source design and optimization (e.g., estimating effects of hypothetical and/or dangerous sources) and in interpreting past events (e.g., in dose reconstruction).

The computer programs we use to model air releases and their impacts feature gaussian-plume descriptions and can be run on personal computers. The CAP88-PC code (Parks 1992), in particular, incorporates dosimetric and health effects data and equations that are advocated by EPA to be used in compliance assessments. Furthermore, CAP88-PC accommodates site-specific input data files to characterize meteorological conditions and population distributions for a site, and the code is relatively easy to use and understand. For these reasons it has been the “workhorse” calculational tool for LLNL’s regulatory compliance assessments since its availability in April 1992, particularly as applied to gradual releases occurring in the course of routine operations.

Radiation Protection Standards

The release of radionuclides from operations at LLNL and the resultant radiological impact to the public is regulated by both the DOE and the EPA.

DOE environmental radiation protection standards, provided under the authority of the Atomic Energy Act of 1954, as amended, and the DOE Organization Act of 1977, as amended, are defined in DOE order 5400.5, *Radiation Protection of the Public and the Environment*. The standards for controlling exposures to the public from operations at DOE facilities that are incorporated in this order are based on recommendations by the International Commission on Radiological Protection (ICRP). The radiological impact to the public is assessed in accordance with DOE Order 5400.1, *General Environmental Protection*. Current index and links to DOE orders appear on the Department of Energy Directives web site (U.S. Department of Energy 1998).

Radionuclide emissions to the atmosphere from DOE facilities are further regulated by the EPA, under the authority of Section 112 of the Clean Air Act, as amended. Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) under 40 CFR Part 61, sets standards for public exposure to airborne radioactive materials (other than radon) released by DOE facilities; radon is regulated by Subparts Q and T. NESHAPs implements the dosimetry system recommended by the ICRP in its Publication 26 (International Commission on Radiological Protection 1977).

The primary DOE radiation standards for protection of the public are 1 millisievert per year (1 mSv / y) or 100 millirem per year (100 mrem / y) effective dose equivalent (EDE) for prolonged exposure of a maximally exposed individual in an uncontrolled area and 5 mSv / y (500 mrem / y) EDE for occasional exposure of this individual. (EDEs and other technical terms are discussed in Supplement 12-1 and defined in the glossary of this report.) These limits pertain to the sum of the EDE from external radiation and the committed 50-year EDE from radioactive materials ingested or inhaled during a particular year that may remain in the body for many years.

The EPA's radiation dose standard, which only applies to air emissions, limits the whole-body EDE to members of the public caused by activities/operations at a DOE facility to 0.1 mSv/y or 100 µSv/y (10 mrem/y). EPA regulations specify not only the allowed levels, but also specify the approved methods by which airborne emissions and their impacts must be evaluated. With respect to all new and/or modified projects, NESHAPs compliance obligations define the requirements to install continuous air effluent monitoring, and to obtain EPA approval for start-up of operations. NESHAPs regulations require that any operation with the potential to produce an annual-averaged off-site dose greater than or equal to 1 µSv/y (0.1 mrem/y), taking full credit for emission-abatement devices such as HEPA filters, must obtain EPA approval prior to startup of operations. This same calculation, but without taking any credit for emission abatement devices, determines whether or not continuous monitoring of emissions to air from this project is required. These requirements are spelled out in Chapter 12: "Air Quality Compliance," in LLNL's *Environmental Compliance Manual* (LLNL 1996b).

Reporting Requirements

All DOE facilities that conduct significant environmental protection programs are required to prepare an annual *Environmental Report* for the site, covering activities of the previous calendar year involving releases to all media via all pathways. LLNL presents this report to the DOE Operations Office in Oakland, CA (DOE/OAK), from which it is distributed to appropriate program senior officials, the Office of Scientific and Technical Information, EPA, and to other agencies and organizations, as appropriate.

The specific DOE Order requiring production and publication of environmental reports was until recently DOE Order 5400.1, mentioned above. Through DOE's Accelerated Orders Reduction effort in 1995–1997, certain requirements expressed in DOE orders were changed, transferred, or canceled. The requirement for production of site annual environmental reports was transferred to DOE Order 231.1, *Environment, Safety, and Health Reporting,* while DOE Order 5400.1 remains the driver for environmental monitoring plan reports. Requirements for "Radioactive Effluent and On-Site Discharge Data Reports" were deleted entirely.

Because DOE facilities and operations are subject to the regulatory requirements of EPA, in particular 40 CFR Part 61, Subpart H, DOE facilities are required to submit an annual report to the EPA, via DOE, showing compliance with NESHAPs (addressing only releases to air). LLNL NESHAPs annual reports are available for the years 1990 through 1997 (Fisher 1991; Isherwood 1992, Surano et al. 1993b; Harrach et al. 1994; Surano et al. 1995a; Gallegos et al. 1996; Gallegos and Biermann 1997; and Gallegos et al. 1998a). Also available are a mid-1991 NESHAPs report (Hagen et al. 1991b) and seven quarterly NESHAPs reports covering the last quarter of 1991 through the second quarter of 1993 (Lamson 1991, 1992; Biermann and Lamson 1992 a and b; Biermann et al. 1992c, 1993; and Surano et al. 1993a).

Notification of “environmental occurrences” resulting in releases of hazardous materials, including but not limited to radionuclides, from both routine operations and unplanned releases is required under a number of environmental laws, regulations, and DOE orders. Documentation is required under DOE Order 232.1, *Occurrence Reporting and Processing of Operations Information*. Each site annual *Environmental Report* documents that year’s environmental occurrences in its “Compliance Summary” chapter (Chapter 2 in this report). Unplanned releases of radioactive material are described annually in both the *Environmental Report* and the NESHAPs report.

Beyond these periodic reporting requirements, DOE Order 5700.6C, *Quality Assurance*, and NESHAPs require that comprehensive and detailed information on LLNL's dose and risk assessment activities be documented as part of a quality assurance program. The LLNL radiological dose assessment guidance document (Harrach 1998) meets this requirement, and provides a level of detail and emphasis that complements the annual reports.

Evaluation of Sources of Radioactive Emissions

The starting point for an assessment of radiological dose is to identify and properly characterize all significant sources of radioactive emissions at a site. Releases to air are emphasized at LLNL, for reasons already noted. Accurate characterization of emission sources is crucial to credible air dispersion and dose modeling, and more generally to correctly gauging the impacts of operations on workers, the public, and the environment. LLNL’s sources are determined in three principal ways: (1) by an inventory process, (2) by direct measurement of the emission rate at the source (continuous effluent monitoring), and (3) by monitoring airborne gases and particulates at selected field points in and around the site (continuous surveillance air monitoring).

Inventoried Sources

Radioactive Materials Management Areas (RMMAs) are areas where radioactive materials are used or stored, or where activation products occur. Several RMMAs at the Livermore site have effluent monitoring systems in place in their exhaust pathways, allowing a direct measurement of their emission rates. For unmonitored or non-continuously monitored RMMAs, source terms for potential releases are inferred from radionuclide inventories, in accordance with EPA methods.

Experimenters and facility managers provide inventory data following a protocol designed and administered by LLNL's Environmental Protection Department. A full (100%) inventory is conducted every three years; only the "key" Livermore site facilities, defined as those in a ranked list that collectively accounted for about 90% of the previous year's Livermore site radiological dose to members of the public, are reinventoried annually. LLNL conducted complete radionuclide inventories for operations in 1994 and again in 1997. In addition, all new RMMAs (ones that commenced operations in the year under evaluation) are inventoried, and radionuclide inventories for all Site 300 explosives experiments are newly evaluated each year. A description of LLNL's inventory process, including examples of the inventory form and accompanying instructions, is given in the guidance document for preparation of NESHAPs annual reports (Gallegos et al. 1998b).

For dose-assessment modeling of unmonitored or noncontinuously monitored sources, the effective emission rate is calculated from radiological usage inventories by applying EPA-specified fractions for potential release to air of materials in different physical states (solid, liquid, powder, or gas) for each radioisotope. The inventory quantity (in curies) is multiplied by a state-dependent release fraction to give the potential annual release to air, i.e., the "effective" emission rate, in accordance with 40 CFR Part 61, Appendix D. If the material is an unconfined gas, the release fraction is 1.0; for liquids and powders, 1.0×10^{-3} is used; and for solids, 1.0×10^{-6}. Data on inventories and descriptions of the diffuse sources can be found in the guidance document (Gallegos 1998) and in NESHAPs annual reports for 1993 through 1997 (Harrach et al. 1994; Surano et al. 1995a; Gallegos et al. 1996; Gallegos and Biermann 1997; and Gallegos et al. 1998a).

In summary, for unmonitored and noncontinuously monitored sources, estimated annual emissions for each radionuclide are based on the product of radionuclide quantity from inventory data and EPA potential-release fractions (physical state dependent release-to-air factors). As discussed later, for some purposes these source emissions may be further reduced by emission-control-device abatement factors, if applicable.

Monitored Sources

Stack Effluent Monitoring

Actual measurements of radionuclides in effluent flow are the basis for reported emissions from continuously monitored sources. Currently six buildings at the Livermore site have continuously monitored discharge points: Buildings 175, 251, 331, 332, 490, and 491. These monitoring systems are described in the LLNL *NESHAPs 1997 Annual Report* (Gallegos et al. 1998a), and in Chapter 4: "Air Effluent Monitoring," in this report. Taken together, these buildings feature about 100 continuously operating monitors.

The most significant monitored source in terms of public dose impact is the Tritium Facility, Building 331, at the Livermore site. Each of the two 30-m stacks on this facility have both a continuous-monitoring ion-chamber alarm system and continuous molecular-sieve samplers. The sieve samplers, which can discriminate between tritiated-water vapor (HTO) and molecular tritium (HT), provide the values used for environmental reporting. The alarmed ion chambers provide real-time tritium concentration release levels (HT and HTO). Monitoring of these stacks provides an accurate measure of the total quantity (number of becquerels or curies) of tritium released to the environment, time-resolved over the course of the year, since the stacks have known properties (height, flow rate, and diameter) and the wind field properties (wind speed, direction, and fluctuation characteristics) are continuously monitored, these data are optimal impute to modeling. The quality of data on source emission rates and wind patterns affects the accuracy of air dispersion and dose assessment modeling more than any other input factor.

Effluent monitoring in the other five facilities is designed to detect radioactive particles. In contrast to monitoring unabated tritium gas effluent in the Building 331 stacks, air samples for particulate emissions are extracted downstream of HEPA filters and prior to the discharge point to the atmosphere. Particles are collected on membrane filters. Sample results are generally found to be below the minimum detectable concentration (MDC) of the analysis; for details, consult Chapter 4 in this report, and the *1997 NESHAPs Annual Report* (Gallegos et al. 1998a).

Among the six continuously monitored facilities at the Livermore site, probably only the Plutonium Facility (Building 332) strictly requires monitoring under the EPA's 0.1 mrem/y standard alluded to earlier in the subsection on radiation standards. The other five are continuously monitored for programmatic or other reasons. For example, continuous monitoring is maintained at the Tritium Facility to provide the most direct and accurate measure of its release of tritium to the atmosphere, and continuous monitoring is maintained at the Heavy Elements Facility (Building 251) in lieu of undertaking a modeling and measurement effort that would be required to demonstrate that monitoring is not needed.

Dose calculations based on effluent monitoring data are expected to be considerably more accurate than those relying on usage-inventory data, physical state release-to-air fractions, and emission-abatement factors.

Surveillance Air Monitoring

To provide wide-area coverage complementing the narrowly focused stack effluent monitoring, surveillance air monitors are placed at selected locations on and in the vicinities of the Livermore site and Site 300 to detect radioactive gases and particulates in ambient air. In addition, dose rates from external penetrating radiation (gamma rays) are measured using thermoluminescent dosimeters (TLDs). Siting of the air monitors and TLDs is done in accordance with the LLNL *Environmental Monitoring Plan* (Tate et al. 1995). Surveillance air monitors are also placed in the vicinity of known diffuse (extended area) emission sources at the Livermore site, specifically those associated with Buildings 292, 331, 514, and 612 and in and around the Livermore site's southeast quadrant, and in on-site locations providing wide coverage of Site 300. These special monitors measure the concentrations of radionuclides present in the air near the sources and allow a direct determination of their environmental impact; see Chapter 5 in this report. In addition to their utility in connection with releases from routine operations, the surveillance air monitors have proven valuable in quantifying the magnitude of accidental releases and their dose impacts.

Determinations of Dose

This section concentrates on the CAP88-PC code, including commenting on its principal features and providing some caveats regarding its use.

Principal Calculational Approaches

LLNL's primary calculational tool for estimating dose and risk from routine operations and most unplanned releases is the computer code CAP88-PC (Parks 1992) as mentioned earlier. Other codes such as EPA's INPUFF code (Peterson and Lavdas 1996) or the HOTSPOT code (Homann 1994) are used as needed to address unplanned releases or short-term releases from experiments or operations.

A complementary approach to deriving EDEs using the built-in dosimetry model in CAP88-PC or other EPA-mandated code is to explicitly calculate doses using mathematical formulas from, e.g., the Nuclear Regulatory Commission's Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977), which incorporates dose conversion factors consistent with those in the International Commission on Radiation Protection's document ICRP 30 (International Commission on Radiological Protection 1980). This approach, outlined in Appendix B of this report, has been used historically at LLNL (preceding the availability of CAP88-PC), and continues to be used, to evaluate annual doses to the public inferred from sampling of local environmental media (air, water, vegetation, and wine).

Identification of Key Receptors: MEI and SW-MEI

When assessing probable off-site impacts, three potential doses are emphasized: (1) the dose to the "sitewide maximally exposed individual member of the public," abbreviated SW-MEI (defined below and in the glossary), which combines the effects of all emission points at a site, for evaluation under the EPA's 100 µSv/y (10 mrem/y) standard; (2) the dose to the maximally exposed individual member of the public (abbreviated MEI), caused by a given emission point on the site (taking no credit for emission abatement devices), for evaluation of the need to conduct continuous monitoring of that emission point under a 1 µSv/y (0.1 mrem/y) standard [1% of the EPA standard in (1)]; and (3) the collective dose to the populations residing within 80 km of either of the two LLNL sites, adding the products of individual doses received and the number of people receiving them. One additional dose frequently needed is identical to that in (2), except that credit *is* taken for abatement devices that are in place; this dose determines the necessity to petition the EPA for permission to start up an activity (new or modified project) that would cause a dose of 1 µSv/y (0.1 mrem/y) or more to the MEI.

The SW-MEI is defined as the hypothetical member of the public at a single publicly accessible location (where members of the public reside or abide) who receives the greatest LLNL-induced EDE from all sources at a site (e.g., the Livermore site). Such public facilities include schools, churches, businesses, and residences. This hypothetical person is assumed to reside at this location 24 hours per day, 365 days per year, continuously breathing air having the ground-level radionuclide concentration, and consuming as at least part of his or her diet foodstuffs and drinking water affected by the releases of radioactivity from the site. Thus, this is not a dose actually received by any individual and should be viewed as a health conservative estimate (i.e., overestimate) of the highest possible dose to any member of the public. The location of the SW-MEI is sensitive to the frequency distribution of wind speeds and directions in a given year and can change from one year to the next. At the Livermore site, the SW-MEI currently is located at the UNCLE Credit Union, about 10 m outside the controlled eastern perimeter of the site. This location lies 948 m from the principal radionuclide source, the Tritium Facility (Building 331), in an east-northeast direction (the typical prevailing wind direction). At Site 300, the SW-MEI currently is located in an experimental area termed “Bunker 2” operated by PRIMEX Physics International. Bunker 2 lies about 300 m outside the east-central boundary of Site 300. This bunker is 2.38 km east-southeast of the principal firing table at Building 801.

Doses in category (2), with and without allowance for abatement, are a main concern when new projects or changes to existing projects (in which releases of radioactivity to the environment may occur) are reviewed for joint compliance with NESHAPs and the National Environmental Policy Act (NEPA). The possible environmental and worker safety issues raised by each proposed activity or project are examined from several different points of view in a process coordinated by LLNL's Environmental Protection Department, including a review and evaluation of potential emissions of radionuclides and air toxics. Air quality compliance requirements for projects are described in Chapter 12 of LLNL’s *Environmental Compliance Manual* (LLNL 1996b).

Modeling Dispersal and Doses with the CAP88-PC Code

CAP88-PC uses a modified gaussian-plume equation to estimate the average dispersion of radionuclides released from up to six co-located sources (stack or area sources). Required input data define the emission sources, the meteorological conditions, the local agricultural characteristics and land use, and the distribution of population surrounding the site. We provide separate data for the Livermore site and Site 300.

Plume rise can be driven either by momentum or buoyancy, or set to a predetermined level. Flat terrain is assumed; variation in radionuclide concentrations due to complex terrain cannot be modeled by CAP88-PC. Assessments are done for a circular grid with a radius of 80 kilometers or less around a facility, allowing up to 20 user-selected radial distances. Concentrations and doses are sector-averaged for each selected radius; i.e., for a given radius from the source, the quoted output value does not pertain just to the plume centerline ground-level value, but is the mean value for that radius across the width of the 22.5-degree sector.

The mathematical models and explicit equations used in CAP88-PC are described in Chapter 8 of Parks’ *User’s Guide for CAP88-PC* (Parks 1992), hereafter referred to as the *User’s Guide*, under the major headings “Environmental Transport,” and “Dose and Risk

Estimates." The differences between CAP88-PC and earlier similar codes are discussed in Appendix E of the *User's Guide.*

In the following, various aspects of CAP88-PC are described, tailoring the remarks to LLNL, where appropriate.

Inputs to CAP88-PC

Required data inputs to CAP88-PC are described in Chapter 4 of the *User's Guide.* Here we summarize some of the principal inputs.

Source Term Specification. CAP88-PC allows stack (point) sources or diffuse (extended area) source-types; volume sources are not an option. A default time period assumed in the code is one year, e.g., input source emission rates have units curies per year (Ci/y) and output dose rates are presented in mrem/y.

The emission rate must be specified for each radionuclide. For monitored sources as discussed above, the continuous sampling data on curies released per unit time for each radionuclide can be used; however, for unmonitored sources, the emission rate is calculated from radiological usage inventories by applying EPA-specified fractions for potential release to air of materials in different physical states (solid, liquid, powder, and gas) for each radioisotope. Similar to physical-state release factors, EPA also specifies control-device abatement factors, associated with various emission-control devices, for use in dispersion and dose models: each high-efficiency-particulate-air (HEPA) filter stage is given a 0.01 emission-reduction factor, venturi scrubbers and electrostatic precipitators are each given a 0.05 factor, and each activated-charcoal filter is given a 0.1 factor. Necessary input information on sources besides emission rate includes stack properties (height, diameter, and volumetric flow rate or temperature of gas in the stack) and the area and elevation of diffuse sources.

Certain sources at LLNL, in particular the Site 300 explosive experiments and a variety of diffuse sources at both sites, such as open-air waste storage and waste accumulation areas, and areas where spills or leaks have occurred, require additional analysis to reduce them to a form suitable for entering into a CAP88-PC input data file. Several such non-standard or special sources are discussed below; more detailed descriptions can be found in any of the NESHAPs annual reports for 1993 through 1997 (Harrach et al. 1994; Surano et al. 1995a; Gallegos et al. 1996; Gallegos and Biermann 1997; and Gallegos et al. 1998a) and in the NESHAPs Annual Report guidance document (Gallegos 1998b).

Meteorological Data. The CAP88-PC code accommodates meteorological data, i.e., sensor-determined data files specifying the frequencies of occurrence for different wind speeds, wind directions, and atmospheric stability classes, and numbers specifying the annually averaged precipitation, temperature, and average height of the atmospheric inversion layer. The atmospheric transport of radioactive materials released to the atmosphere from LLNL is a sensitive function of meteorological conditions. Wind speed, direction, and fluctuation in direction are measured continuously at two meteorological towers, one at the Livermore site and the other at Site 300. Seven Pasquill-Gifford atmospheric stability classes are specified as part of the wind datafile. The meteorological data reside on a DOS computer diskette and are converted into a CAP88-PC input wind file in accordance with EPA guidelines. In Parks' *User's Guide,* Section 4.3.3, Chapter 7, and Appendix B describe the meteorological data and its conversion for use with CAP88-PC. Tables and windroses showing meteorological data for the Livermore site and Site 300 are published annually in the *Environmental Report* (e.g., see Chapter 1 in this report) and the NESHAPs Annual Report (e.g., Gallegos and Biermann 1997).

Population Data. The code also accepts population data files, defining the distribution of population as a function of distance and direction out to a radial distance of 80 km (about 50 miles) from site-center. For specifying populations, each area element in sixteen 22.5-degree compass sectors is bounded above and below by arcs with radii from the set of user-selected distances, and on its sides by radial line segments separating the sectors. In 1993, population distributions centered on the two LLNL sites (treated separately) were compiled from 1990 census data and used as input to the model calculations of collective doses for all persons living within 80 km. (The preparation and installation of population files for use with CAP88-PC is described in Appendix F of the *User's Guide.*) In 1996 and again in 1997, new and improved population files were created for both LLNL sites, based on 1990 census data as before, but made more accurate through the use of commercially available, computer-map-based population data and ArcView geographic information system software; see the *NESHAPs Annual Report for 1996* (Gallegos and Biermann 1997). Key population centers affected by LLNL emissions are the relatively nearby communities of Livermore and Tracy, the more distant large metropolitan areas of Oakland, San Francisco, and San Jose, and the San Joaquin Valley communities of Stockton and Modesto. Within an 80-km radius centered on the Livermore site, 6.3 million residents reside; the corresponding number is 5.4 million for Site 300.

Agricultural Data. The code allows specification of food sources, agricultural characteristics, and land use parameters, as established by the EPA. Arrays of milk cattle, beef cattle, and agricultural crops are automatically generated by the code based on which state (of the United States) is specified, but the user can override these in favor of non-default values for the densities of beef cattle, milk cattle, and the fraction of land cultivated for vegetable crops. Food-source classifications available for selection by the user are designated “urban,” “rural,” “local,” “regional,” “imported,” and “entered,” where the last type allows the user to specify the fraction of vegetables, milk, and beef that are home-produced, produced in the assessment area (within 80 km), and imported. The particular choice to represent a site can significantly affect the size of the ingestion dose. We conservatively characterize the two LLNL sites as “local” for our collective and individual dose determinations, with one exception. Since there are no dairies located close to either LLNL site, milk is considered to be imported for the purposes of calculating individual doses at locations near the sites, e.g., those to the MEI and SW-MEI. Agricultural data inputs for CAP88-PC are described in Section 4.3.5 and Appendix C of the *User’s Guide.*

Radioisotopes. Up to 36 radionuclides can be included in a single run of CAP88-PC, chosen from a total library of 265 radionuclides. Two complex (the U-238 and Th-232 chains) and four simple (the Cs-137, Ba-140, Mo-99, and Pb-210 chains) radioactive decay chains are available, which allow the user to take into account radioactive decays occurring in the plume as it disperses; this feature is only of interest for short-lived radioisotopes. Most of the radionuclides used by LLNL are included among the 265 in the library; for the few that are not, suitable surrogate or health-impact “equivalent” radionuclides must be selected from the CAP88-PC list. In some cases involving mixtures of radionuclides, LLNL experimenters do not have isotopic analyses, but can only identify their radionuclide inventory as gross alpha, gross beta, or gross gamma radiation, or mixed fission products (MFPs). In such cases, for modeling purposes we conservatively represent a given number of curies of gross alpha by the same number of curies of Pu-239; similarly Sr-90 is used to represent both gross beta and MFPs, and ^{137}Cs is used to represent gross gamma radiation.

CAP88-PC Outputs

The CAP88-PC code calculates radionuclide dose rates, concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from ingestion of food produced in the assessment area (using the Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models (U.S. Nuclear Regulatory Commission 1977). Summaries of calculated exposures and risks are broken down by organ, pathway, and radionuclide. The output of CAP88-PC is presented in the form of seven “reports,” as described in Section 6.2 of the *User's Guide*.

Dose and risk are estimated in CAP88-PC by combining the inhalation and ingestion intake rates, and the air and ground surface concentrations with dose and risk conversion factors in ICRP Publication 26 (International Commission on Radiological Protection 1977). These estimates from CAP88-PC are applicable only to low-level chronic exposures, since the health effects and dosimetric data it uses are based on low-level chronic intakes.

Caveats on Use of CAP88-PC

A number of caveats and other observations on the use of the CAP88-PC code are presented in the LLNL Radiological Dose Assessment Guidance Document (Harrach 1998). A few of the most important of these are given here.

Dose-Rate Conversion Factors in CAP88-PC. Interrogating a CAP-88PC output file showing the dose rate conversion factors used by the code for the 265 radionuclides it includes, one finds that for many radionuclides the factors differ slightly from those in standard references, such as Federal Guidance Report No. 11 (Eckerman et al. 1988). These factors were compiled for the code in 1989 by Eckerman and Nelson (Eckerman and Nelson 1989), using the best information available at that time, which included small differences for such things as standard breathing rates and blood transfer rates relative to those used by Eckerman et al. in producing Federal Guidance Report No. 11. The dose-rate conversion factors in CAP88-PC are discussed in a 1989 EPA report on risk assessment (Eckerman and Nelson 1989).

Assessment Assumptions Regarding Tritium. Several aspects of tritium dose estimates based on CAP88-PC, each important but unrelated to the others, should be noted. (1) Tritium (H-3) emissions account for the major dose from operations at the Livermore site. Tritium exists in two major chemical forms: tritium oxide or vapor (HTO) and elemental molecular tritium (HT), and these forms are distinguished in monitoring the emission of tritium from the stacks of LLNL's Tritium Facility (Building 331). The HTO that enters the body is distributed throughout the entire body and eliminated at the same rate as body water. Only a very small fraction of HT is retained. The effective dose equivalent from exposure to elemental tritium in air is lower by a factor of about 25,000 than an equal exposure from tritium oxide (Eckerman et al. 1988). Thus, emissions of HTO are the major contributor to the tritium dose to the MEI and SW-MEI. Regarding the collective or population dose to people living within 80 km of the Livermore site, HT could contribute a non-negligible part of the tritium dose by means of its conversion to HTO. But conversion of HT to HTO during plume transport and deposition is a complicated (and inefficient) process, so we typically ignore the HT component; a more conservative alternative would be to treat all HT as HTO for the purposes of the population dose calculation. CAP88-PC assumes HTO is meant whenever an inventory of H-3 is input to the code. (2) The dose-rate-conversion factor that CAP88-PC uses for inhalation-plus-dermal-absorption of tritium is out-dated and more conservative than values quoted in recent literature. In 1980, the ICRP in its publication ICRP 30 recommended that skin intake should be 50% of lung intake, revising its earlier recommendation stated in ICRP 2 (1959) that skin intake equals lung intake. The CAP88-PC dose-rate-conversion factor for tritium contains the 1959 recommendation, producing an inhalation-plus-dermal-absorption dose that is too large by a factor 4/3 relative to the more recent recommendation (see Attachment 3, Gallegos et al. 1996). (3) Finally, CAP88-PC overestimates the ingestion dose from tritium. According to a recent (October 1997) memorandum from Barry Parks, the degree of this overestimate varies depending on input selections. It can be traced to three key assumptions implicit in the software that may not be immediately apparent to the user: (a) the contribution of home-grown food, (b) the distances at which food is produced, and (c) the number of people consuming locally produced food. Documentation on how these overestimates can occur is available on the Internet at the address http://www.er.doe.gov/production/er-80/cap88/tritium.html.

Special Modeling Problems

Unusual releases may require special measurements and calculations to characterize the source. Both the Livermore site and Site 300 provide important examples in this regard.

Diffuse Sources

Often these unusual releases fall into the classification of "diffuse sources." One example is leakage of tritium-contaminated water from an underground tank at Building 292 at the Livermore site, which resulted in the release of tritium to the atmosphere via soil moisture evaporation and root-uptake and transpiration by plants, from one pine tree in particular. A discussion of this source appears in the section on "Livermore Site Diffuse Sources" in the *1993 NESHAPs Annual Report* (Harrach et al. 1994), and subsequent NESHAPs annual reports provide updates. Emissions from certain difficult-to-characterize sources sometimes can be inferred from data obtained by LLNL's routine surveillance air monitoring program, in which the ambient air at selected locations within and outside of Laboratory boundaries is continuously monitored for tritium gas and radioactive particulates. An example in this category is the diffuse tritium source occupying the Building 612 waste storage yard at the Livermore site, which is characterized using data from an air monitor in the yard. Another example is the diffuse source caused by resuspension of depleted uranium in soil at Site 300; an array of seven air monitors allows the annual-average concentration of uranium in air over the site to be determined. A calculational model described in the *1995 NESHAPs Annual Report* (Gallegos et al. 1996) was developed to distinguish between the contribution made to these data by LLNL-operations-contributed uranium, compared to the considerably larger contribution from naturally-occurring uranium. The routine air surveillance monitoring program also has been particularly useful in registering the magnitude of unplanned releases; an example of this type is provided by the accidental release of curium-244 from Building 513 discussed earlier in the subsection on Unplanned Releases.

The reader is referred to LLNL NESHAPs annual reports for descriptions and evaluations of other such sources.

Modeling Dose Impacts from Explosives Experiments at Site 300

Modeling releases of radionuclides into the atmosphere from explosive tests at Site 300 requires special consideration compared to conventional stack or area sources. During experiments, an explosive device containing depleted uranium is placed on an open-air firing table and detonated. A cloud of explosive decomposition products promptly forms over the firing table, typically reaching a height of several hundred meters, and disperses as it is carried downwind. (The depleted uranium does not contribute to the explosive energy, which is entirely of chemical origin.) In the absence of measurements of the properties of the cloud, we assume for modeling purposes that it reaches an initial height and size governed by known empirical scaling laws for detonations (Bowers, personal communication), in which the scaling parameter is the TNT-equivalent explosive mass. The specific equation we use for the maximum elevation reached by the plume is

$$H_{max}(m) = (92.6) \times [\ M_{TNTeq}(kg)\ ]^{0.25} + 10,$$

where the explosive TNT-equivalent mass is approximated as

$$M_{TNTeq}(kg) = (1.3) \times M_{TotalHE}(kg),$$

and $M_{TotalHE}$ is the total mass of high explosives of all types used in the detonation. The (assumed) spherical cloud of decomposition products has a diameter given by the similar scaling relation

$$D(m) = (6.4) \times [\ M_{TNTeq}(kg)\ ]^{0.333}.$$

The multiplicative factors in the first and third of these expressions have dimensions: in the first equation 92.6 is not a pure number but is 92.6 $m / (kg)^{0.25}$ and in the third the number 6.4 has units $m / (kg)^{0.333}$. Then expressing M_{TNTeq} in kilograms results in a value for H_{max} and D in meters.

Isotopic ratios for depleted uranium are used. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 in depleted uranium occur in the weight-percentages 99.8, 0.2, and 5×10^{-4}, respectively. The inventory for each explosive experiment specifies the mass of depleted uranium used: $M_{DU}(kg)$. Multiplying this quantity by the respective specific activities gives the total number of curies for each isotope in the cloud.

In summary, the data for the isotopes in depleted uranium are:

U-238: Fraction by weight = 0.998
Specific activity = 3.33×10^{-4} Ci / kg
No. curies of U-238 = 3.33×10^{-4} (Ci / kg) $\times$ M_{DU}(kg);

U-235: Fraction by weight = 2.0×10^{-3}
Specific activity = 2.14×10^{-3} Ci / kg
No. curies of U-235 = 4.29×10^{-6} (Ci / kg) $\times$ M_{DU}(kg);

U-234: Fraction by weight = 5.0×10^{-6}
Specific activity = 6.20 Ci / kg
No. curies of U-234 = 3.10×10^{-5} (Ci / kg) $\times$ M_{DU}(kg).

LLNL's modeling of these Site 300 explosive tests to determine the resultant off-site doses is based on the CAP88-PC code. CAP88-PC simulates each explosive experiment or shot as a continuous, year-long, stack-type emission (i.e., the total activity released in a time period of order one minute in the explosion is treated as though it were released gradually over the course of an entire year), with meteorological data appropriate to annual-average conditions at Site 300. As inputs to the code, H_{max} is used as the fixed plume height and D as the stack diameter.

Clearly, this modeling approach does not match the physical events well, and we could easily do better. An alternative INPUFF-code-based modeling methodology that would treat these transient explosive events as short-duration puffs, and which would incorporate some of the effects of the hilly terrain at Site 300, was submitted to EPA for approval in 1992 (Biermann et al. 1993). EPA Region 9 Headquarters decided that from the standpoint of regulatory compliance the use of CAP88-PC to model these explosives experiments was adequate, despite the recognized difficulties.

In the absence of detailed data about the explosive experiments, we make several highly conservative assumptions in our calculations. We assume that (1) 100% of the depleted uranium present in the experiment is completely aerosolized and dispersed as a cloud; (2) the median particle size is the CAP88-PC default value of 1 µm; (3) the lung clearance class for inhaled material is class Y. (Note: Clearance of inhaled material from the lung to the blood or to the gastrointestinal tract depends on the chemical form, e.g., U_3O_8, of the radionuclide, and is classified as D, W, and Y, respectively, for clearance times of order days, weeks, and years.) These assumptions may produce a dose that is too high by a factor of 10 or more. We believe a more realistic release-to-air fraction for the uranium is no greater than 0.2, but we lack sufficient documentation to use a value other than 1.0. Also, the median particle size may be much larger than 1 µm and a sizable fraction of the aerosolized particles might be more properly characterized by lung clearance class D, which produces a dose by inhalation of depleted uranium that is smaller by a factor of about 16 compared to class Y. Even with these assumptions, the MEI and SW-MEI individual doses, as well as the collective or population dose, that we calculate for the explosive experiments are very small (see, e.g., the Summary and Conclusions section of this chapter).

Radiological Doses from 1997 Operations

About 150 emission points were included in the 1997 modeling runs. These sources were of several types: stacks and other exhaust pathways from buildings (including emissions from all RMMAs in which radiological operations took place); diffuse area sources generally external to buildings; and open-air firing tables at Site 300 where explosives experiments were conducted.

The Livermore site diffuse sources are Hazardous Waste Management's Tank Farm at Building 514 and the waste storage yard and drum sampling areas at its Building 612 Hazardous Waste Management Yard; a tank leakage area at Building 292; the Southeast Quadrant of the Livermore site where resuspension of contaminated soil occurs; and a waste accumulation area at Building 331. Diffuse sources at Site 300 included the total land area on site where evaporation of tritium and resuspension of depleted uranium can occur, and a low-level-waste staging area at Building 804. Fewer explosives experiments containing radioactive materials were conducted at the Site 300 explosives-testing facilities in 1997, compared to the recent past; this was reflected in the smallest estimated potential dose to the Site 300 SW-MEI in the last eight years, when evaluations of public dose impacts from these experiments commenced. This section presents the main results of our calculations for 1997 operations, summarizes them, and exhibits in tables and a figure the trends in these results over recent years. For further details, especially regarding the diffuse sources at the two sites, see the *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998a).

Dose Breakdown by Facility

Table 12-1 lists all LLNL facilities and diffuse sources having the potential to release radioactivity into the environment during 1997. For each facility or building, the table gives the number of stacks or other exhaust avenues discharging radionuclides, lists the dose to the sitewide maximally exposed public individual (SW-MEI) caused by the dominant emission point at each facility, and identifies the types of operations occurring

Table 12-1. Sources of radiation dose from LLNL releases (measured and potential) to air: stacks and other exhaust pathways from buildings containing radioactive materials management areas, and diffuse area sources.[a,b]

Bldg	Facility	Potential emission points	Maximum EDE[c] (μSv/y)	Operations
151	Isotope Sciences; Chemistry & Materials Science Environmental Services Lab	22	1.5×10^{-4}	Application of nuclear and isotope sciences to a wide range of problems; sample analysis of waste streams and environmental media for radionuclide content
166	Laser Isotope Separation	1	0.0[d]	Conversion of uranium to halides and oxides
174	Laser Isotope Separation	1	1.5×10^{-11}	Pulse laser experimentation
175	Laser Isotope Separation	6	0.0[d]	Cleaning and refurbishing of uranium parts
177	Laser Isotope Separation	4	9.4×10^{-4}	Sample preparation, cleaning of parts, processing uranium oxide powders, liquid uranium corrosion studies
194	Physics & Space Technology	2	9.4×10^{-5}	High-energy linear accelerator (LINAC), positron beam generation and experiments
212	Physics & Space Technology	2	6.8×10^{-11}	Physics experiments; residual contamination from previous operation of rotating target neutron source (no longer operating)
222	Chemistry & Materials Science	6	1.3×10^{-6}	Chemical analyses, cleaning equipment, waste samples preparation and analysis, decontamination, spectroscopy, gravimetric
231	Chemistry & Materials Science, Engineering, Safeguards & Security	13	2.8×10^{-6}	Materials research and testing, spin forming, heat treatment, electron-beam welding, grinding/polishing, casting, microscopy, sample preparation, storage
	Mechanical Engineering Vault	1	0.0[d]	Storage of radionuclides
235	Chemistry & Materials Science	3	3.1×10^{-11}	Material structure studies, precision cutting, ion implantation, metallurgical studies
241	Chemistry & Materials Science	3	1.8×10^{-6}	Materials properties research and testing
251	Heavy Elements			Storage of transuranic isotopes prior to disposal
	Seismically Hardened area	4	0.0[d]	
	Unhardened areas	36	3.0×10^{-4}	
253	Hazards Control	7	3.3×10^{-8}	Radiochemical analyses
254	Hazards Control	1	1.1×10^{-10}	Radiochemical analyses of bioassays; analytical services
255	Hazards Control	2	9.8×10^{-5}	Radiation standards and instrument calibration
281	Chemistry & Materials Science	7	1.6×10^{-8}	Sample preparation; wet chemistry laboratory
292	Environmental Programs	3	2.3×10^{-5}	Tritium contamination from prior operations
298	Laser Fusion	3	3.5×10^{-5}	Laser fusion targets research and development

Table 12-1. Sources of radiation dose from LLNL releases (measured and potential) to air: stacks and other exhaust pathways from buildings containing radioactive materials management areas, and diffuse area sources[a,b] (continued).

Bldg	Facility	Potential emission points	Maximum EDE[c] (μSv/y)	Operations
321	Materials Fabrication	5	3.1×10^{-7}	Forming, machining, and manufacturing of uranium parts
322	Mechanical Engineering	1	4.3×10^{-9}	Cleaning and plating of depleted uranium
327	Mechanical Engineering	1	1.6×10^{-7}	Nondestructive ultrasonic material evaluation
331	Tritium	2	7.2×10^{-1}[d]	Tritium research; decontamination and decommissioning operations
332	Plutonium	8	0.0[d]	Plutonium research
361	Biological and Biotechnology Research	13	4.6×10^{-6}	Radiolabeling; biological dosimetry; DNA sequencing, hybridization, and repair; human genome; enzyme assay; radioactive probes
362	Biological and Biotechnology Research	2	9.5×10^{-8}	Dose preparation for animal experiments
363	Biological and Biotechnology Research	3	1.1×10^{-13}	Dispensing samples
364	Biological and Biotechnology Research	2	4.9×10^{-7}	DNA labeling; isolation and purification
365	Biological and Biotechnology Research	3	1.4×10^{-8}	Housing research animals, animal research, equipment decontamination
366	Biological and Biotechnology Research	1	5.9×10^{-8}	DNA labeling
381	Laser Fusion	1	7.0×10^{-9}	Tritium handling for laser target research
391	NOVA Laser	1	7.4×10^{-5}	Housing of high-energy laser; fusion target irradiation
419	Hazardous Waste Management	2	0.0[d]	Decontamination and decommissioning
490	Laser Isotope Separation	1	0.0[d]	U.S. Enrichment Corporation isotope separation operations, including vaporization of uranium for enrichment
491	Laser Isotope Separation	1	0.0[d]	U.S. Enrichment Corporation isotope separation operations
513	Hazardous Waste Management	3	2.2×10^{-3}	Sampling, treatment, and storage of hazardous, mixed, and radioactive waste; drum repacking and sludge stabilization; shredding of solid waste
514	Hazardous Waste Management (see also diffuse sources below)	2	5.1×10^{-3}	Waste consolidation, vacuum filtration of treated waste water
612	Hazardous Waste Management	4	1.4×10^{-2}	Waste consolidation, drum crushing, lab analysis of waste treatment and treatability samples

Table 12-1. Sources of radiation dose from LLNL releases (measured and potential) to air: stacks and other exhaust pathways from buildings containing radioactive materials management areas, and diffuse area sources[a,b] (concluded).

Bldg	Facility	Potential emission points	Maximum EDE[c] (μSv/y)	Operations
625	Hazardous Waste Management	2	8.4×10^{-8}	Repackaging of wastes
810A	Site 300 Firing Table support	1	1.2×10^{-7}	Assembly of explosives
801	Site 300 Firing Table at 801	—[e]	1.1×10^{-1}	Detonation of explosives
	Livermore site diffuse sources[f]	6	See next six entries below.	Storage areas and contaminated ground
292	Underground storage tank	1	6.1×10^{-7}	Tank leakage of tritiated water transpired by plants
331	Tritium Facility (external)	1	1.7×10^{-2}	Outdoor waste accumulation area
514	Hazardous Waste Management Tank Farm	1	9.5×10^{-3}	Liquid waste processing, treatment, and storage
612	Hazardous Waste Management	2	1.6×10^{-1}	Storage of low-level waste; drum sampling and waste accumulation areas (WAAs)
—	Southeast quadrant of Livermore site	1	3.1×10^{-3}	Contaminated ground
	Site 300 diffuse sources[f]	3	See next three entries below.	Contaminated ground and water
—	All Site 300 land area	1	1.1×10^{-3}	Evaporation of tritium from contaminated soil and water
—	All Site 300 land area	1	8.7×10^{-2}	Resuspension of uranium in contaminated soil
804	Open area	1	6.0×10^{-6}	Low-level waste staging area

a *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998a).

b RMMAs in which no operations using radionuclides took place in 1997 or in which all radionuclides were encapsulated or sealed for the entire year are not included in this table. Table entries refer to routine operations, not unplanned releases.

c The maximum effective dose equivalent to the sitewide maximally exposed individual (SW-MEI) member of the public from a single discharge point, among all discharge points modeled for the indicated facility or building. The SW-MEI is defined in the section on Maximally Exposed Individuals and Populations.

d The effluents from the facility are monitored. Zeroes refer to monitored values below the minimum detectable concentration, as discussed in the Monitored Facilities section.

e Open air dispersal in 1997.

f Diffuse sources are described briefly in the section on specifications of source terms, and more fully in the *LLNL 1997 NESHAPs Annual Report* cited in footnote a.

in the building or facility, or the nature of the diffuse source, as the case may be. Corresponding data is included for the Site 300 explosive experiments. Facilities in which no operations using radionuclides took place in 1997 or in which any radionuclides present were encapsulated or sealed for the entire year are excluded from **Table 12-1**.

The principal feature shown in the table is that LLNL has a fairly large number of very small sources. As shown more clearly in subsequent tables, a few sources account for nearly all of the dose to members of the public, and the total dose is quite small compared to federal standards for radiation protection of the public.

Unplanned Releases

The foregoing discussion, as well as all entries in **Table 12-1**, refer to releases occurring during the course of normal operations. Unplanned or accidental releases must be accounted for, as well, in determining the total dose to the public from LLNL activities. As noted in Chapter 2 of this report (both in the subsection on “National Emission Standards for Hazardous Air Pollutants” and in the subsection on “Hazardous Waste Permits”), there was one unplanned release of radioactivity from the Livermore site in 1997, concerning an escape of curium-244 (^{244}Cm) from Building 513 during an operation in which HEPA air filters were being shredded prior to disposal off site as radioactive waste. The Environmental Protection Department’s routine surveillance air monitors recorded data during the hours spanning the primary release event and in the days following, at three principal locations, designated SALV (237 m SE of Building 513), CRED (579 m NE), and Building 531 (389 m NNW). In addition, radiation monitors of several types provided data on the indoor air environment, including respirator data, continuous air monitoring data, and high-volume air sampler data. Based on these data, three different theoretical approaches were used to quantify the amount of ^{244}Cm released from Building 513 and determine the probable impact of this release on the public. (1) Because the SW-MEI dose is precisely the dose received at the CRED surveillance air monitor (i.e., this monitor is positioned at the location of our SW-MEI for the Livermore site, the UNCLE Credit Union), the CRED monitor reading, together with the known dose-rate-conversion factor for ^{244}Cm, provided a direct, modeling-independent and meteorological-data-independent estimate of dose to the SW-MEI of 2.1×10^{-3} μSv (2.1×10^{-4} mrem). (2) Air-dispersion modeling was used in concert with the surveillance air monitoring data to make quantitative estimates of both the amount of radioactivity released to the environment in this accident, and the potential dose to the SW-MEI that occurred as a consequence. The CAP88-PC code was run in a “back-calculation” mode, wherein the unknown source strength is “tuned” to produce output results consistent with the concentrations of Cm^{244} recorded at the three surveillance air monitor locations. The total release of Cm^{244} was selected to be the largest value for which the calculated concentrations agreed (within plus or minus the 2σ measurement uncertainty) with the mean concentrations shown by all of these air monitors. Using parameters corresponding to a "most likely" release scenario, the air-dispersion modeling calculation yielded the result that about 400 nanocuries (nCi, 1 nCi = 1×10^{-9} Ci) were released into the atmosphere, producing a SW-MEI dose that is 57% as large as the aforementioned model-independent estimate based solely on the CRED monitor data. (3) Finally, an analysis of the building ventilation dynamics, utilizing data from radiation monitors located inside Building 513, concluded that the most likely released quantity was 190 Ci. Using this source term in the same air dispersion modeling run as in (2) produces a SW-MEI dose that is 27% of the CRED monitor result. Our final "best estimate" of the SW-MEI dose from this unplanned release of ^{244}Cm from Building 513 is then the CRED monitor result given in (1) above, since it is the most conservative of the three. It should be kept in mind that modeling approaches such as used in (2) and (3) give a *range* of credible estimates for released quantity and dose, caused by making different, but still plausible, assumptions concerning the conditions of the release; we have emphasized the "most likely" values for simplicity and consistency with other doses quoted in this report. This incident and its analyses are described in the *LLNL NESHAPs 1997 Annual Report* (Gallegos et al. 1998a) and in a detailed letter from LLNL to EPA Region IX (Fisher 1998).

There were no unplanned atmospheric releases at Site 300 in 1997.

Doses to Sitewide Maximally Exposed Individuals

The 1997 calculated EDE to the SW-MEI from Livermore site point sources was 0.78 µSv (0.078 mrem). Emissions from the two 30-m stacks at the LLNL Tritium Facility (Building 331) accounted for most of this: 0.75 µSv (0.075 mrem), or 96%. For the Livermore site, the SW-MEI dose caused by diffuse emissions in 1997 was 0.19 µSv (0.019 mrem). Combining point and diffuse sources, the total annual dose was 0.97 µSv (0.097 mrem), divided 80%/20% between point and diffuse source emissions. This is practically the same as last year's total; **Table 12-2** shows the trend over the past eight years.

Table 12-2. Doses (in μSv) calculated for the sitewide maximally exposed individual for the Livermore site and Site 300, 1990 to 1997.

Year	Total dose	Point source dose	Diffuse source dose
Livermore site			
1997	0.97	0.78	0.19
1996	0.93	0.48	0.45
1995	0.41	0.19	0.22
1994	0.65	0.42	0.23
1993	0.66	0.40	0.26
1992	0.79	0.69	0.10
1991	2.3	—[a]	—[a]
1990	2.4	—[a]	—[a]
Site 300			
1997	0.20	0.11	0.088
1996	0.33	0.33	0.0045
1995	0.23	0.20	0.03
1994	0.81	0.49	0.32
1993	0.37	0.11	0.26
1992	0.21	0.21	—[b]
1991	0.44	0.44	—[b]
1990	0.57	0.57	—[b]

[a] Diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991.

[b] No diffuse emissions were reported at Site 300 for years prior to 1993.

The calculated EDE to the SW-MEI at Site 300 in 1997 was 0.20 μSv (0.020 mrem), with 0.11 μSv (0.011 mrem) caused by emissions in the course of explosives experiments at the Building 801 firing table. The remaining 0.088 μSv (0.0088 mrem), or about 45% of the total, was attributed to Site 300 diffuse sources; resuspension of LLNL-contributed uranium in surface soils throughout Site 300 was responsible for nearly all of this dose from diffuse sources.

The 1997 firing tables total is down from values in recent years (see the “point source dose” column for Site 300 in Table **12-2**). **Table 12-3** shows the potential public dose values attributed to firing table experiments for 1990 through 1997, correlated with the total amounts of depleted uranium and the total quantity of high explosives used in the experiments. (Only experiments that included depleted uranium are considered; most have none.) The data show that variations from year to year in these doses mainly reflect differences in the amount of depleted uranium used in the tests.

Table 12-3. Annual dose to the SW-MEI from explosives experiments on firing tables at Site 300, 1990–1997, related to the total quantity of depleted uranium used in the experiments and the total quantity of high explosives (HE) driving the detonations.

Year	Dose to SW-MEI		Total depleted U used in experiments (kg)	Total HE used in depleted U experiments (kg)
	(μSv)	(mrem)		
1997	0.11	0.011	163	122
1996	0.33	0.033	272	112
1995	0.20	0.020	165	199
1994	0.49	0.049	230	134
1993	0.11	0.011	99	74
1992	0.21	0.021	151	360
1991	0.44	0.044	221	330
1990	0.57	0.057	340	170

Table 12-4 lists the facilities that were primarily responsible for the LLNL dose; the contributions from all emission points at each facility have been summed. These facilities accounted for approximately 97% of the total EDE resulting from Livermore site operations and more than 99% of the total EDE from Site 300 operations. The dominant radionuclide(s) are indicated for each facility. Tritium was the overall dominant radionuclide at the Livermore site, accounting for more than 95% of the Livermore site dose. At Site 300, practically the entire dose was due to the isotopes present in depleted uranium having atomic numbers 238, 235, and 234.

The relative significance of inhalation and ingestion is different for tritium and uranium and depends on the assumptions made about the origin of food consumed by a person receiving the dose. For the conditions we assumed when assessing individual doses, namely that milk is imported while the remainder of the food is produced locally, ingestion accounted for 81% of the dose in the case of tritium, versus 19% for inhalation. For uranium, these numbers are nearly reversed: 17% by the ingestion pathway, versus 83% via inhalation. For both uranium and tritium, external doses from air immersion and ground irradiation were negligible.

Table 12-4. Major contributors to LLNL's radiation dose via airborne emissions, 1997.

Facility or operation(a)	Dominant radionuclide(s)	EDE at SW-MEI(b)	
		μSv/y	mrem/y
Livermore site			
B331/Tritium Facility	^{3}H	0.75	0.075
B612 Yard Area(c)	^{3}H	0.16	0.016
B331 Waste Accum. Area(c)	^{3}H	0.017	0.0017
B612	^{238}U, ^{228}Th, ^{239}Pu, ^{137}Cs, ^{234}U, etc.	0.014	0.0014
Sum of all other sources	Various	0.029	0.0029
Total		**0.97(d)**	**0.097(d)**
Site 300			
B801/firing table	^{238}U, ^{234}U, ^{235}U	0.11	0.011
Soil resuspension(c)	^{238}U, ^{234}U, ^{235}U	0.087	0.0087
Total		**0.20(d)**	**0.020(d)**

a The facilities cited here are discussed in the text of this report and in more detail in the NESHAPs annual reports.

b These doses represent the sum of all emission points from a given facility (for example, both stacks on Building 331), in contrast to the dose values in Table 12-1, which represent the dose from the single largest emission point on each facility. The sitewide maximally exposed individual (SW-MEI) member of the public is defined in the section on Maximally Exposed Individuals and Populations.

c Diffuse sources (see text).

d These Livermore site and Site 300 totals represent 0.97% and 0.20%, respectively, of the federal standard.

Ranked List of Radionuclides Used in LLNL Operations

A ranked list showing the most significant 20 of 110 radioisotopes contributing to the radiological dose to the SW-MEI at the Livermore site is presented in **Table 12-5**. In this table, each radionuclide has been assigned a ranking factor that is determined by weighting the effective potential release quantity (in curies) times the inhalation dose rate conversion factor for each particular isotope; ranking is done relative to tritium (tritiated water vapor). Dose rate conversion factors used in the calculations are taken from the CAP88-PC code.

Table 12-5. Leading radioisotopes (with respect to public dose impact) in use at the Livermore site and Site 300 for 1997. The isotopes have been ordered by ranking the potential and measured emissions according to the inhalation dose rate conversion factor for the isotope.

Radionuclides	Ranking factor relative to HTO	Radionuclides	Ranking factor relative to HTO
H-3 (HTO)	1.0	Th-232	4.1×10^{-4}
U-238	2.4×10^{-2}	Th-228	1.1×10^{-4}
U-234	6.4×10^{-3}	O-15	1.1×10^{-4}
Am-241	3.7×10^{-3}	Am-244	4.2×10^{-5}
Gross alpha	3.5×10^{-3}	Gd-146	2.7×10^{-5}
Pu-239	2.1×10^{-3}	P-32	2.5×10^{-5}
CM-244	8.9×10^{-4}	Gross beta	2.3×10^{-5}
Pu-238	8.7×10^{-4}	Am-243	2.0×10^{-5}
N-13	6.6×10^{-4}	Mixed fusion products	1.2×10^{-5}
U-235	5.1×10^{-4}	U-233	7.8×10^{-6}

Trends in Dose to the SW-MEI

The trends in dose to the SW-MEI from emissions at the Livermore site and Site 300 over the last eight years are shown in **Figure 12-1** and **Table 12-2**. No diffuse emissions were reported at Site 300 for years before 1993, so comparison for total dose can only be made with the values for 1993 through 1996. In addition, diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991. The general trend, particularly over the last half-dozen years, shows year-to-year fluctuations around a quite low dose level, staying at or below about 1% of the federal standard.

The SW-MEI dose estimates we report are intentionally conservative, erring on the side of predicting potential doses that are several times higher than would actually be experienced by any member of the public. Our modeling of Site 300 firing table operations is especially so, as explained in the section on Special Modeling Problems. Our conservative modeling methodology over-predicts the quantity of uranium that is aerosolized and released to air in explosives experiments by at least a factor of five, we believe, and over-estimates the efficiency of long-range dispersal of material in these experiments.

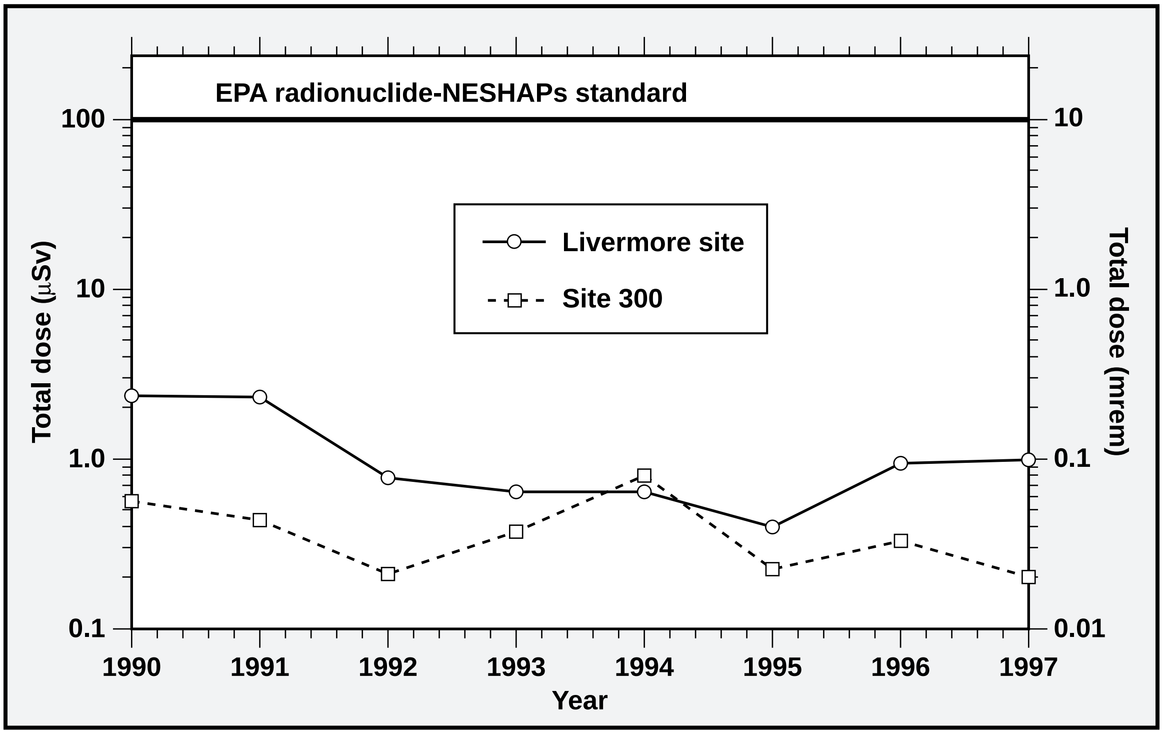

Figure 12-1. Dose to the sitewide maximally exposed individual member of the public, 1990 to 1997.

Collective Doses to Exposed Populations

Population doses, or collective EDEs, for both LLNL sites were calculated out to a distance of 80 km in all directions from the site centers using CAP88-PC. As noted earlier, CAP88-PC evaluates the four principal exposure pathways: ingestion through food and water consumption, inhalation, air immersion, and irradiation by contaminated ground surface.

The collective EDE caused by 1997 Livermore site operations was 1.5 person-rem (0.015 person-Sv), similar to the 1996 result of 1.1 person-rem (0.011 person-Sv). The corresponding collective EDE from Site 300 operations in 1997 was 7.2 person-rem (0.072 person-Sv). This value is lower than the 1996 value of 10 person-rem (0.10 person-Sv). The difference results from use of lesser amounts of depleted uranium in the explosives experiments conducted at Site 300 in 1997 (see **Table 12-2**).

Table 12-6 compares background and medical-treatment-related doses to the maximum potential doses caused by LLNL operations. The population doses caused by LLNL operations are some 400,000 times smaller than ones from natural background radiation, and the individual dose to the maximally exposed public individual is about 3000 times smaller.

Table 12-6. Comparison of background (natural and man-made) and LLNL radiation doses, 1997.

Location/Source	Individual dose[(a)]		Population dose[(b)]	
	(μSv)	(mrem)	(person-Sv)	(person-rem)
Livermore site sources				
Atmospheric emissions	0.97	0.097	0.015	1.5
Site 300 sources				
Atmospheric emissions	0.20	0.020	0.072	7.2
Other sources[(c)]				
Natural radioactivity[(d,e)]				
Cosmic radiation	300	30	1,900	190,000
Terrestrial radiation	300	30	1,900	190,000
Internal (food consumption)	400	40	2,500	250,000
Radon	2000	200	12,500	1,250,000
Medical radiation (diagnostic procedures)[(e)]	530	53	3,300	330,000
Weapons test fallout[(e)]	11	1.1	68	6,800
Nuclear fuel cycle	4	0.4	25	2,500

a For LLNL sources, this dose represents that experienced by the sitewide maximally exposed individual member of the public.

b The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of LLNL (approximately 6.3 million people for the Livermore site and 5.4 million for Site 300), calculated with respect to distance and direction from each site.

c From National Council on Radiation Protection (NCRP 1987a and b).

d These values vary with location.

e This dose is an average over the U.S. population.

Summary and Conclusion

The annual radiological dose from all emissions at the Livermore site and Site 300 in 1997 was found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard for DOE facilities, which limits total annual emissions of radionuclides to the ambient air to 100 µSv/y (10 mrem/y). Using EPA-mandated computer models, actual LLNL meteorology, and population distributions appropriate to the two sites, the dose to the LLNL sitewide maximally exposed members of the public from 1997 operations were:

- Livermore site: 0.97 µSv (0.097 mrem) (80% from point-source emissions, 20% from diffuse-source emissions);
- Site 300: 0.20 µSv (0.020 mrem) (55% from explosive experiments, classified as point-sources, 45% from diffuse-source emissions).

The major radionuclides accounting for the doses were tritium at the Livermore site and the three isotopes in depleted uranium (^{238}U, ^{235}U, and ^{234}U) at Site 300).

The collective effective dose equivalent or population dose attributable to LLNL operations in 1997 was estimated to be 0.015 person-Sv (1.5 person-rem) for the Livermore site and 0.072 person-Sv (7.2 person-rem) for Site 300. These doses include exposed populations of 6.3 million people for the Livermore site and 5.2 million for Site 300, living within a distance of 80 km from the site centers, based on 1990 census data.

Table 12-6 compares the individual and collective radiation doses from atmospheric releases at LLNL to other sources of radioactivity to which the U.S. population is exposed. The dose to the maximally exposed member of the public resulting from Livermore site and Site 300 operations is seen to be about 3000 times smaller than the doses from background radiation (see also **Figure 12-2** in Supplement 12-1 below), and the population dose from LLNL operations is about 400,000 times smaller than those caused by natural radioactivity in the environment.

We conclude that the potential radiological doses from LLNL operations were well within regulatory standards and very small compared to doses normally received by these populations from natural background radiation sources, even though highly conservative assumptions were used in the determinations of LLNL doses. These maximum credible doses indicate that LLNL's use of radionuclides had no significant impact on public health during 1997.

Chapter 12 Supplements

Supplement 12-1: Radiation Basics

Natural and Man-Made Radiation. By far the greatest part of radiation received by the world's population comes from natural sources—primarily cosmic rays that impinge on the earth's atmosphere from space and radionuclides naturally present in our environment, such as radioactive materials in soil and rocks. Among these terrestrial sources are carbon-14, potassium-40, rubidium-87, uranium-238, thorium-232, and radioactive elements, such as radon, that arise from decay of uranium and thorium. The source of human exposure to natural radiation can be external (from substances staying outside the body) or internal (from substances inhaled in air or ingested in food and water). Individual doses vary with location. The level of cosmic radiation increases with altitude, because there is less air overhead to act as a shield, and the earth's poles receive more cosmic radiation than the equatorial regions, because the earth's magnetic field diverts the radiation. The levels of terrestrial radiation differ from place to place around the United States and around the world, mainly owing to variations in soil and rock composition.

Adding to this pervasive natural or background radiation is man-made radiation from radionuclides used in medicine, consumer products, the production of energy, and the production of nuclear weapons. Exposure to man-made sources can be controlled more readily than exposure to most natural sources. However, nuclear explosives tested in the atmosphere in the 1950s and 1960s spread radioactivity across the surface of the globe, and the nuclear reactor accident at Chernobyl in 1986 affected a large area. At present, medical treatment is the largest common source of public exposure to man-made radiation. Individual medical doses vary enormously—someone who has never had an x-ray examination may receive zero medical dose while patients undergoing treatment for cancer may receive many thousands of times the annual average dose they would receive from natural radiation. Another source of public exposure to man-made radiation is consumer products, including luminous-dial watches, smoke detectors, airport x-ray baggage inspection systems, and tobacco products.

Radioactivity. Generally, naturally occurring isotopes are stable, but notable exceptions include carbon-14, potassium-40, thorium-232, uranium-235, and uranium-238, which occur naturally but are radioactive. Nuclear decay divides into three main categories: alpha, beta, and gamma. Alpha decay is the spontaneous emission of an alpha particle (a bound state of two protons and two neutrons—the nucleus of a helium atom) from a nucleus containing a large number of protons (most commonly 82 or more). Beta decay is the spontaneous conversion of a neutron to a proton in the nucleus with the emission of an electron, and gamma decay is the spontaneous emission of high-energy photons (high-frequency electromagnetic radiation) by nuclei.

Radioisotopes decay at quite different rates; the "half-life," or length of time for half of the atoms to decay, spans a wide range from small fractions of a second to millions of years. For example, tritium (the radioactive form of hydrogen) has a 12.3-year half-life, compared to 24,131 years for plutonium-239.

Some radioisotopes decay by forming radioisotopes that in turn decay into other radioisotopes until a stable state is achieved. For example, an atom of uranium-238 can undergo alpha decay, leaving behind a daughter, thorium-234, which is also radioactive. The transformations of the decay chain continue, ending with the formation of lead-206, which is a stable isotope.

Radioactivity can be hazardous because radiation (alpha particles, beta particles, or gamma rays) can be released with great energy. This energy is capable of altering the electronic configuration of atoms and molecules, especially by stripping one or more electrons off the atoms of the irradiated material, thereby disrupting the chemical activity in living cells. If the disruption is severe enough to overwhelm the normal restorative powers of the cell, the cell may die or become permanently damaged. Cells are exposed to many naturally occurring sources of disruption, including naturally toxic chemicals in food, microbes that cause disease, high-energy radiation from outer space (cosmic rays), and heat and light (including the sun's rays, which can cause sunburn and skin cancer). Consequently, cells and living organisms have evolved the capacity to survive limited amounts of damage, including that caused by radioactivity.

Three main factors determine the radiation-induced damage that might be caused to living tissue: the number of radioactive nuclei that are present, the rate at which they give off energy, and the effectiveness of energy transfer to the host medium, i.e., how the radiation interacts with the tissue. Alpha radiation can be halted by a piece of paper and can scarcely penetrate the dead outer layers of skin. Radioisotopes that give off alpha radiation are generally not health hazards unless they get inside the body through an open wound or are ingested or inhaled. In those cases, alpha radiation can be especially damaging because its disruptive energy can be deposited within a small distance, resulting in significant energy deposition in a few cells. Beta radiation from nuclear decay typically penetrates a centimeter or two of living tissue. It therefore deposits energy over many cells, decreasing the damage to any single cell. Gamma radiation is extremely penetrating and can pass through most materials, only being significantly attenuated by thick slabs of dense materials, such as lead.

Measurement of Radioactivity and Dose. The rate at which a nucleus decays is expressed in units of becquerels, abbreviated Bq, where 1 becquerel is one decay per second, or alternatively in curies, Ci, where 1 curie equals 3.7×10^{10} (37 billion) decays per second, or 3.7×10^{10} Bq (approximately equal to the decay rate of 1 gram of pure radium). Becquerels and curies are not measures of the effect of radiation on living tissue. This depends on the efficiency of energy deposition as the radiation traverses matter.

The amount of energy deposited in living tissue is called the “dose.” The amount of radiation energy absorbed per gram of tissue is called the “absorbed dose,” and is expressed in units of rads or grays (Gy), where 1 Gy equals 100 rads. Because an absorbed dose produced by alpha radiation is more damaging to living tissue than the same dose produced by beta or gamma radiation, the absorbed dose is multiplied by a quality factor to give the dose equivalent. The quality factor for alpha radiation is 20; for beta and gamma, 1. The dose equivalent is measured in units of rem or sieverts (Sv); 1 Sv equals 100 rem. Also commonly used are the millirem (mrem) and the millisievert (mSv), which are one-thousandth of a rem and sievert, respectively.

Just as one type of radiation can be more damaging than others, some parts of the body are potentially more vulnerable to radiation damage than others, so the different parts of the body are given weightings. For example, a given radiation dose from iodine-131 is more likely to cause cancer in the thyroid than in the lung. The reproductive organs are of particular concern because of the potential risk of genetic damage. Once particular organs are weighted appropriately, the dose equivalent becomes the “effective dose equivalent,” also expressed in rem or sievert.

The effective dose equivalent (EDE) describes doses to individuals. When individual effective dose equivalents received by a group of people are summed, the result is called the “collective effective dose equivalent,” often referred to as the “population dose,” and is expressed in person-sievert or person-rem. Finally, to account for the long-term effects of radionuclides as they continue to decay and affect generations of people, we calculate the dose over many years, summing the effect over time. This is termed the “collective effective dose equivalent commitment.” Most of our discussion in this chapter deals with the effective dose equivalent and the collective effective dose equivalent.

Doses from Natural and Man-Made Radioactivity. The average radiation dose from natural sources in the United States, according to the National Council on Radiation Protection and Measurement (NCRP 1987b), is 3.0 mSv/y (300 mrem/y). Approximately 0.3 mSv/y (30 mrem/y) of this exposure comes from high energy radiation from outer space (cosmic rays). Terrestrial sources, mainly radionuclides in rock and soil, also account for approximately 0.3 mSv/y (30 mrem/y) of the average natural dose. Another significant part of the dose comes from radionuclides we ingest through food and drink, resulting in approximately 0.4 m Sv/y (40 mrem/y). Potassium-40 and carbon-14 are common radionuclides in food.

The remaining 2.0 mSv / y (200 mrem / y) or 67% of the average dose from natural sources in the United States comes from radon gas. Radon is one of the major radionuclides produced by uranium decay, and our inhalation dose is dominated by radon's short-lived decay products. **Figure 12-2** shows the distribution of annual radiation doses from natural and other common sources.

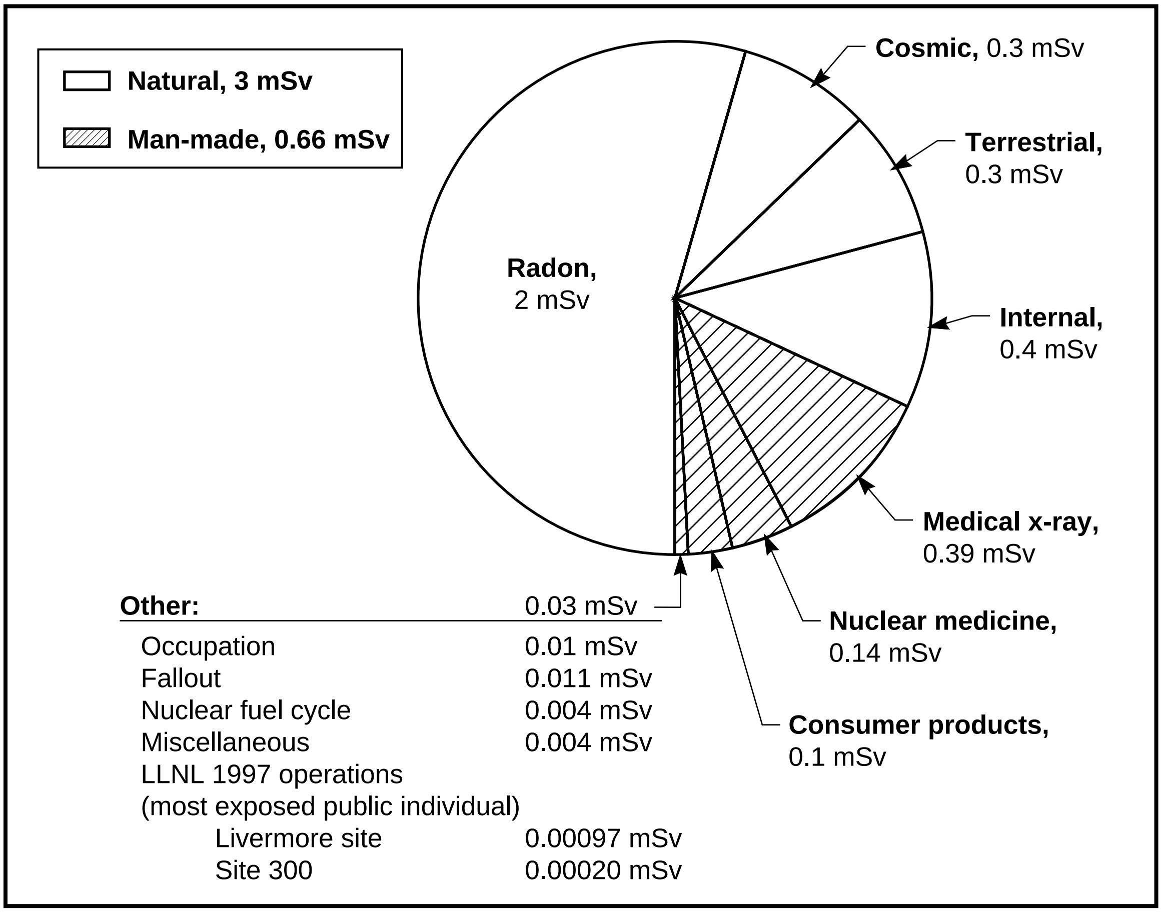

Figure 12-2. Typical annual radiation doses from natural and man-made sources (National Council on Radiation Protection 1987b).

Radon dose varies significantly with geographic location. Levels several times higher than the average occur in some regions of the United States, while at LLNL and its environs doses as low as half the average are typical. Radon gas seeps out of the earth worldwide. Radon in water and natural gas provide additional but less important sources of radon in homes. The U.S. Environmental Protection Agency (EPA) has instituted a major program to educate the public regarding the effects of naturally occurring radon (U.S. Environmental Protection Agency and U.S. Department of Health and Human Services 1986).

The dose received by any particular individual from natural background sources depends on other lifestyle choices or conditions besides place of residency, eating habits, and occupation. For example, the dose from cosmic radiation received in a one-way airplane flight between New York and Los Angeles is about 2.5 mrem; two U.S. coast-to-coast round trip flights give about the same radiation exposure as a standard chest x-ray.

We noted earlier that medical treatment is the largest common source of public exposure to man-made radiation, and most of it is delivered as medical x-rays. These contribute 0.39 mSv (39 mrem) to the average whole-body annual dose in the United States, but individual doses vary enormously. For example, a typical dental x-ray series results in a skin dose (not whole body) of approximately 2.5 mSv (250 mrem). Nuclear medicine contributes 0.14 mSv (14 mrem) to the average dose, and consumer products add 0.1 mSv (10 mrem). For a typical member of the public, radiation from medical procedures and consumer products result in a dose of approximately 0.63 mSv/y (63 mrem/y). The average dose from other man-made sources, including fallout from nuclear testing, is less than 0.03 mSv (3 mrem). As described in this chapter, the contributions from LLNL operations to the dose of even the most affected resident are on the order of 0.1 mrem/y or less, and would not be discernible on the scale shown in **Figure 12-2**; LLNL's contributions are listed under "Other" in the figure.

Supplement 12-2: Radiation Control Measures at LLNL

Radioisotopes used at LLNL include uranium, transuranics, biomedical tracers, tritium, and mixed fission products. Protection of employees and the public from the uncontrolled release of radioactive materials into the environment is a primary consideration for LLNL. This effort takes several forms, as summarized here.

When an operation or facility is designed, a thorough assessment of potential radiation hazards is conducted, and radioisotope-handling procedures and work enclosures are determined for each project, depending on the isotope, the quantity being used, and the type of operations being performed. Radioisotope handling and working environments include glove boxes, exhaust hoods, and laboratory bench tops. The controls might include limiting physical access and using shielding, filters, and remote handling equipment. Exhaust paths to the atmosphere include HEPA (high-efficiency particulate air)-filtered stacks, stacks lacking abatement devices, roof vents, and ordinary room air ventilation channels. Facility Safety Analysis Reports and Facility Safety Procedures are written to document the need for specific measures and to spell out the requirements for maintenance, training, emergency response, and other administrative control measures.

When a facility is occupied for use, an Operational Safety Procedure (OSP) is written that specifies actions to be taken in conducting a research or development project. This procedure is reviewed by environmental analysts, industrial hygienists, and health physicists to assess the safety of the operation, its compliance with current occupational health and environmental standards, and the adequacy of proposed engineering and administrative controls. The OSP also specifies training requirements for personnel. This part of the control program enables LLNL personnel who work with radiation and radioactivity to recognize and prevent the execution of unsafe operations.

Another form of LLNL's radiation control program involves direct monitoring of the workplace environment. This includes sampling of the air and surfaces in facilities where radioactive materials are handled, and includes personal dosimetry and bioassay programs used to monitor potential worker exposure to direct radiation and radioactive isotopes. This monitoring program helps to determine the effectiveness of a facility's radiation control program as well as providing information on worker exposures.

The surveillance and effluent monitoring of radiation in air, water, soils, vegetation, and sewage, as discussed in Chapters 2 and 4 through 11 of this report, play an important role in LLNL's program to control radiation releases. These measurements can signal anomalous releases, should they occur, and directly gauge the degree of success of LLNL's radionuclide discharge control program in limiting exposures of the public.

Development of the Livermore Valley and the San Joaquin Valley has enlarged the populations and decreased the distance between sources of emissions and the residents who might be exposed. People live and work within several hundred meters of LLNL's boundaries. It is therefore increasingly important that our assessments provide the best information possible regarding the radiological impact of LLNL operations.

13 QA

Quality Assurance

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Donald H. MacQueen

Introduction

Quality assurance (QA) is a system of activities and processes put in place to ensure that monitoring and measurement data meet user requirements and needs. Quality control (QC) consists of procedures used to verify that prescribed standards of performance in the monitoring and measurement process are attained. QA requirements for environmental monitoring of DOE facilities are mandated by DOE orders and guidance. DOE Order 5400.1 identifies QA requirements for radiological effluent and surveillance monitoring and specifies that a QA program consistent with DOE Order 5700.6 be established. The latter order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs. The DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) requires that an Environmental Monitoring Plan be prepared that contains a QA section discussing the applicable elements of the American National Standards Institute / American Society of Mechanical Engineers (ANSI / ASME) NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989).

LLNL conducted QA activities in 1997 at the Livermore site and Site 300 in accordance with a plan based on DOE Order 5700.6C (Pendexter 1993), which prescribes a risk-based, graded approach to QA. This process promotes the selective application of QA and management controls based on the risk associated with each activity, maximizing the effectiveness and efficiency in resource use.

LLNL environmental sampling is conducted according to procedures published in Appendix A of the LLNL Environmental Monitoring Plan (Tate et al. 1995). Environmental monitoring samples are analyzed by LLNL or commercial laboratories using EPA standard methods when available. When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. The radiochemical methods used by LLNL laboratories are described in procedures unique to the laboratory performing the analyses. When analyses are performed by independent contractors, LLNL requires that their laboratories be certified by the State of California for the analyses performed for LLNL. In addition, LLNL requires all analytical laboratories to maintain adequate QA programs and documentation of methods.

13 Quality Assurance

Quality Assurance Activities

Nonconformance reporting and tracking is an LLNL quality assurance process aimed at ensuring that EPD activities meet EPD requirements. In 1997, Nonconformance Reports (NCRs) related to environmental monitoring were down from the 137 written in 1995 and the 106 written in 1996, to 87 written in 1997. As in previous years, most environmental monitoring NCRs covered missing samples. Unreliable air particulate sampling equipment has been a significant source of NCRs in the past; however, upgrades to that equipment over the last several years have resulted in a significant reduction in the number of NCRs. (See Chapter 5 for a more detailed account of equipment improvements.)

Half of the 24 NCRs attributed to analytical laboratories resulted from problems such as laboratory courier error or incorrect paperwork. These errors were corrected. Other problems such as missed holding times, late analytical results, and typographical errors on data reports accounted for the remaining NCRs attributable to the analytical laboratories. Many of these were corrected in the short-term by reanalysis or resampling, so required results were not lost. These problems continue to reappear, and they are addressed with the appropriate laboratory as they arise.

Of the 25 NCRs related to sewer monitoring, 13 could be attributed to failure to perform scheduled sampling, maintenance activities, or tasks performed incorrectly. The remaining 12 were related to minor equipment problems. Changes in the sewer monitoring procedures should minimize errors in the upcoming year.

Analytical Laboratories

In March of 1996, LLNL and Lawrence Berkeley National Laboratory (LBNL) began using new contracts with six off-site analytical laboratories (Garcia and MacQueen 1997).

All off-site analytical laboratories were audited in early 1997 and determined to be capable of fulfilling the requirements of the LLNL/LBNL analytical Statement of Work at that time. Areas for improvement were documented in the audit report for each laboratory and the EPD Assurance Manager and the Lead Auditor for each audit met with laboratory representatives to review those areas and begin to develop an implementation schedule for corrective actions.

During the summer of 1997, one of the laboratories experienced internal problems of such severity that its parent company eventually declared bankruptcy and closed the laboratory in January 1998. The closure had no impact on LLNL environmental monitoring.

Participation in Laboratory Intercomparison Studies

The LLNL Chemistry and Materials Science Environmental Services Environmental Monitoring Radiation Laboratory (CES EMRL) and the Hazards Control Department's Analytical Laboratory (HCAL) participated in both the Environmental Protection Agency's (EPA) Environmental Monitoring Systems Laboratory (EMSL) intercomparison studies program and the DOE Environmental Monitoring Laboratory (EML) intercomparison studies program in 1997. A review of the EMSL study indicates that 37 of 37 analyses reported by CES and 10 of 10 analyses reported by HCAL fell within established acceptance control limits. For the EML studies, 82 of 84 reported by CES and 10 of 10 results reported by HCAL fell within the established acceptance control limits.

The HCAL also participated in four EPA Water Pollution and Water Supply intercomparison studies for metals during 1997. Review of these results shows that values for 32 of 34 samples fell within established acceptance control limits.

The intercomparison study results, as well as the follow-up explanation and response for data that fell outside the acceptance control limits are presented in the Data Supplement. Contract laboratories are also required to participate in laboratory intercomparison programs; however, permission to publish their results for comparison purposes was not granted for 1996.

The potential effects of unacceptable intercomparison study results on routine data have not been fully determined or evaluated. A joint EPD/CES performance evaluation committee has been formed to create a systematic process for evaluating laboratory performance using traceable standards. A method for evaluating the results of intercomparison studies will be developed by that committee.

Duplicate Analyses

Duplicate or collocated samples are distinct samples of the same matrix collected as closely as possible to the same point in space and time, and are intended to be identical in all respects. Collocated samples processed and analyzed by the same organization provide intralaboratory precision information for the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples processed and analyzed by different organizations provide interlaboratory precision information for the entire measurement system (U.S. Environmental Protection Agency 1987). Collocated samples may also be used to identify errors—for example, mislabeled samples and data entry errors.

Tables 13-1 through **13-3** present statistical data for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 13-1** and **13-2** contain data pairs in which both values are above the detection limit, and radiological results for which an estimated activity was reported. The tables exclude radiological values for which only a minimum detectable activity was reported. In addition, **Table 13-2** excludes radiological results for which the reported value is negative. **Table 13-3** contains data pairs in which either or both values are below the detection limit.

If there were more than eight data pairs with both results above the detection limit, precision and regression analyses were performed; the results are presented in **Table 13-1**. Precision is measured by the percent relative standard deviation (%RSD); see the EPA *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. Environmental Protection Agency 1987).

Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, values above 30% are common. The results for %RSD given in **Table 13-1** are the 75th percentile of the individual precision values. Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with slope equal to one and intercept equal to zero, as illustrated in **Figure 13-1**. Allowing for normal analytical variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be >0.8.

If there are eight or fewer data pairs with both results above the detection limit, the ratios of the individual duplicate sample pairs are averaged; the average, minimum, and maximum ratios for selected analytes are given in **Table 13-2**. The mean ratio should be between 0.7 and 1.3.

If one of the results in a pair is below the detection limit, then the other result should be less than two times the detection limit. **Table 13-3** identifies the sample media and analytes for which at least one pair failed this criterion. Analytes with fewer than four pairs total are omitted from the table.

Table 13-1. Quality assurance duplicate sampling. Summary statistics for analytes with more than eight pairs in which both results were above the detection limit.

Matrix	Analyte	N[(a)]	%RSD[(b)]	Slope	$r^{2(c)}$	Intercept
Air	Beryllium	14	22.7	0.903	0.98	0.337 (pg/m^3)
	Gross alpha[(d)]	104	73.9	0.481	0.22	2.267 (pCi/L)
	Gross beta	104	14.3	0.972	0.92	5.045 (pCi/L)
	Plutonium-239[(d,e)]	11	75.7	0.126	0.07	1.79×10^{-10} (pCi/L)
	Uranium-235 by mass	11	6.11	0.949	0.98	3.53 ($\mu g/m^3$)
	Uranium-238 by mass	11	8.77	0.953	0.98	4.529 ($\mu g/m^3$)
	Tritium	34	17.7	1.12	0.94	–0.09 (pCi/m^3) (air)
Radiation dose	Radiation dose	29	2.74	0.839	0.84	2.56 (mrem)
Ground water	Arsenic	22	10.3	0.947	0.99	0.000 (mg/L)
	Barium	17	4.29	0.966	1.0	0.000 (mg/L)
	Chloride[(e)]	11	1.31	1.05	0.69	18.8 (mg/L)
	Chromium	13	10.1	0.845	0.97	0.000 (mg/L)
	Fluoride	11	5.66	0.994	0.96	0.018 (mg/L)
	Gross alpha[(d)]	22	58.7	0.874	0.77	0.867 (pCi/L)
	Gross beta[(d)]	22	16.4	0.755	0.64	1.89 (pCi/L)
	Nickel	9	7.44	0.951	0.99	0.000 (mg/L)
	Nitrate (as N)	12	6.22	1.06	0.99	–0.39 (mg/L)
	Nitrate (as NO_3)	25	2.98	1.06	0.99	–1.47 (mg/)L
	Orthophosphate	9	6.73	0.985	0.92	0.002 (mg/)L
	Radium-226	10		1.20	0.89	0.051 (pCi)/L
	Sodium	9	4.56	1.04	0.95	–3.09 (mg/L)
	Specific conductance	10	0.804	0.907	0.96	119 (μmho/cm)
	Sulfate[(e)]	11	6.40	0.836	0.68	50.0 (mg/L)
	Uranium-234 and uranium-233	19	8.09	0.929	0.99	0.160 (pCi/L)
	Uranium-235 and uranium-236[(d)]	19	28.3	0.666	0.89	0.018 (pCi/L)
	Uranium-238	19	12.0	1.01	1.0	0.029 (pCi/L)
	Vanadium	9	3.75	1.01	1.0	–0.00 (mg/L)
	pH[(e)]	10	0.552	0.756	0.34	1.90 (pH units)
Sewer	Gross alpha[(d)]	53	89.4	0.354	0.12	2.00 (pCi/L)
	Gross beta	53	22.0	0.726	0.95	5.27 (pCi/L)
	Tritium	53	93.2	0.918	0.83	24.7 (pCi/L)

a Number of duplicate pairs included in regression analysis.

b 75th percentile of percent relative standard deviation (%RSD), where %RSD = $\left(\frac{200}{\sqrt{2}}\right)\left(\frac{|x_1 - x_1|}{x_1 + x_2}\right)$ and x_1 and x_2 are the reported concentrations of each routine-duplicate pair.

c Coefficient of determination.

d Outside acceptable range of slope or r^2 due to variability.

e Outside acceptable range of slope or r^2 due to outliers.

Table 13-2. Quality assurance duplicate sampling. Summary statistics for selected analytes with eight or fewer pairs in which both results were above the detection limit.

Media	Analyte	N[(a)]	Mean ratio	Minimum ratio	Maximum ratio
Aqueous	Gross alpha	1	14.0	14.0	14.0
	Gross beta	1	1.4	1.4	1.4
	Tritium	1	0.84	0.84	0.84
Ground water	Thorium-232	1	0.23	0.23	0.23
	Trichloroethene	8	1.3	0.87	3.5
	Tritium	8	0.99	0.53	1.3
Rain	Tritium	2	1.0	0.89	1.1
Runoff (from rain)	Gross alpha	5	2.5	0.70	6.2
	Gross beta	5	0.96	0.68	1.4
Soil	Beryllium	1	1.1	1.1	1.1
	Cesium-137	2	0.89	0.82	0.95
	Plutonium-239/240	2	0.99	0.84	1.1
Vegetation	Tritium, per gram dry weight	6	1.1	0.61	1.9

[a] Number of data pairs.

[b] Outside acceptable range of 0.7–1.3, for mean ratio.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times will have different amounts of variability.

These analyses show generally good agreement between routine samples and quality assurance duplicates: approximately 82% of the pairs have a precision better than 30%. Data sets not meeting our precision criteria generally fall into one of two categories. The first category, outliers, can occur because of data transcription errors, measurement errors, or real but anomalous results. Of 31 data sets reported in **Table 13-1**, four did not meet the criterion for acceptability because of outliers. **Figure 13-2** illustrates a set of collocated pairs with one outlier. The other category of results that does not meet the criterion for acceptability consists of data sets in which there is a lot of scatter. This tends to be typical of measurements at extremely low concentrations as illustrated in **Figure 13-3**.

Table 13-3. Quality assurance duplicate sampling. Summary statistics for analytes with at least four pairs in which one or both results were below the detection limit.

Medium	Analyte	Number of inconsistent pairs	Number of pairs	Percent of inconsistent pairs
Air	Tritium	1	17	5.8
	Tritium (H_2O)	1	17	5.8
Ground water	Aluminum	1	16	6.3
	Ammonia nitrogen (as N)	1	5	20
	Copper	2	27	7.4
	Di-*n*-octylphthalate	1	12	8.3
	Iron	2	13	15.4
	Nitrite (as N)	1	11	9.1
	Selenium	1	13	7.7
	TNT	1	7	14.3
	Zinc	1	29	3.4
Storm water	Iron	3	4	75
	Tritium	1	5	20
Sewer	Chromium	2	5	40
	Silver	1	6	16.7
	Trichlorofluoromethane	1	4	25
	o-Cresol	1	4	25

Low concentrations of radionuclides on particulates in air highlight this effect even more because one or two radionuclide-containing particles on an air filter can significantly impact results. Another cause of high variability is sampling and analytical methodology. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 31 data sets in **Table 13-1**, six show sufficient variability in results to make them fall outside of the acceptable range. Some data sets exhibit both outliers and high variability.

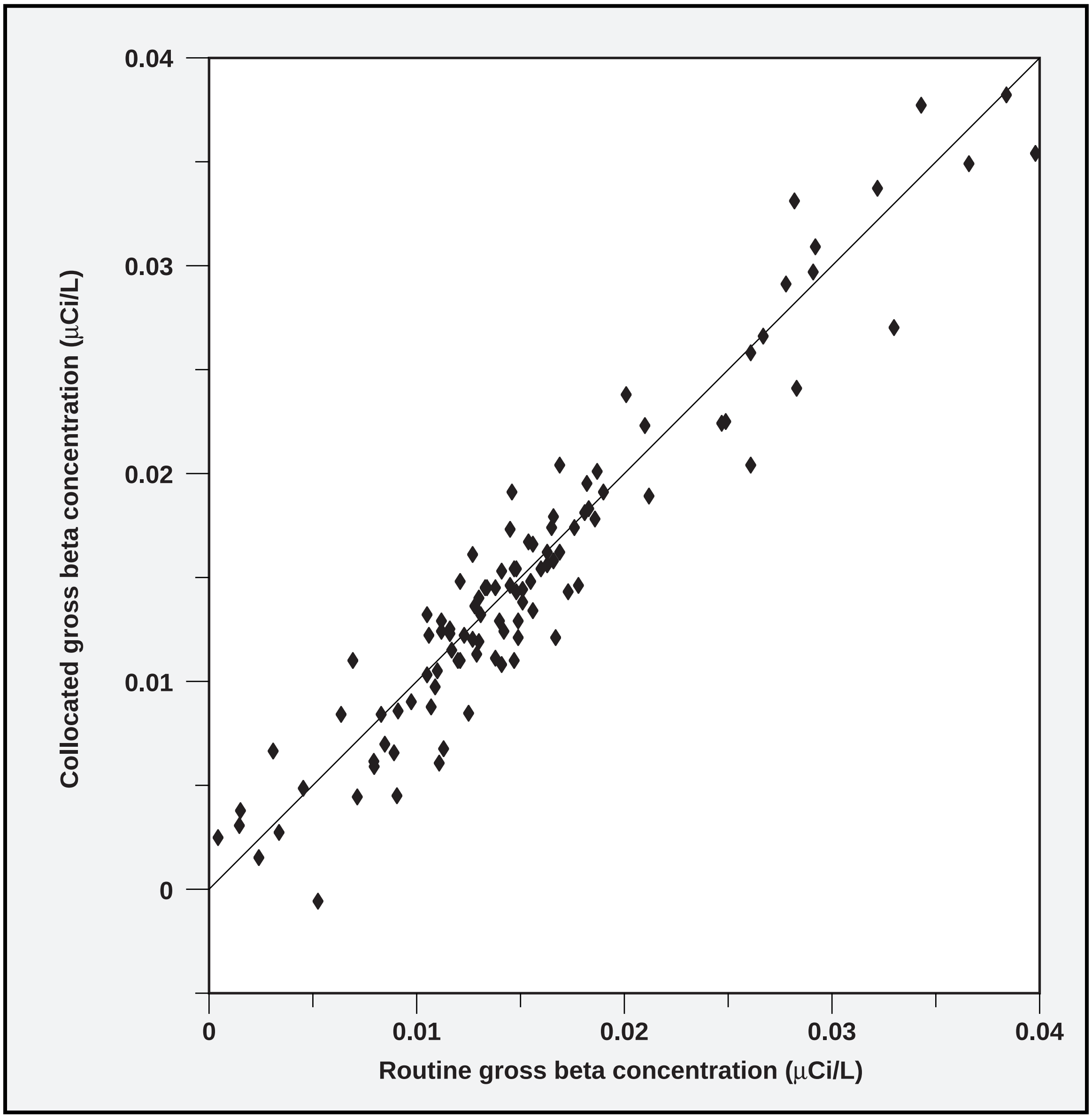

Figure 13-1. Gross beta concentrations from collected samples. These data lie close to a line with slope equal to one and an intercept equal to zero.

Deviations and Changes to the Sampling Program

The sections that follow summarize changes to the environmental sampling effort made during 1997, deviations from planned environmental sampling, and omissions of data expected from regularly scheduled samples.

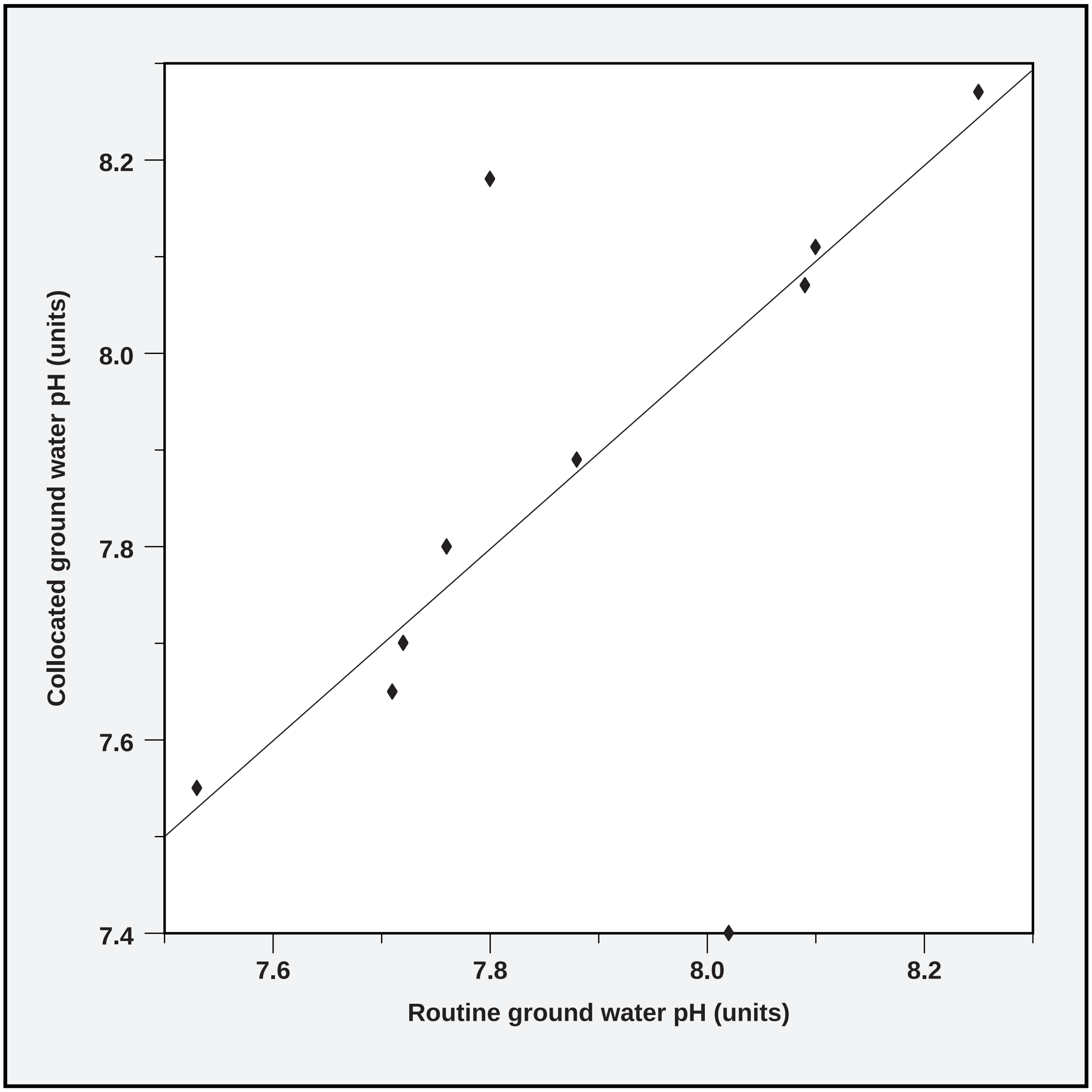

Figure 13-2. Ground water pH from collected samples showing one outlier.

Changes to Environmental Monitoring Networks

Changes that were made to environmental monitoring networks in 1997 are summarized in **Table 13-4**. The air particulate network was split into two separate networks—one for monitoring radiological parameters and the other for monitoring beryllium—in 1997. This change was made because of the need to use different type of filters for collecting beryllium and radiological samples. Livermore Valley air particulate monitoring locations L-ALTA and L-RRCH were abandoned in 1997 because agreements for

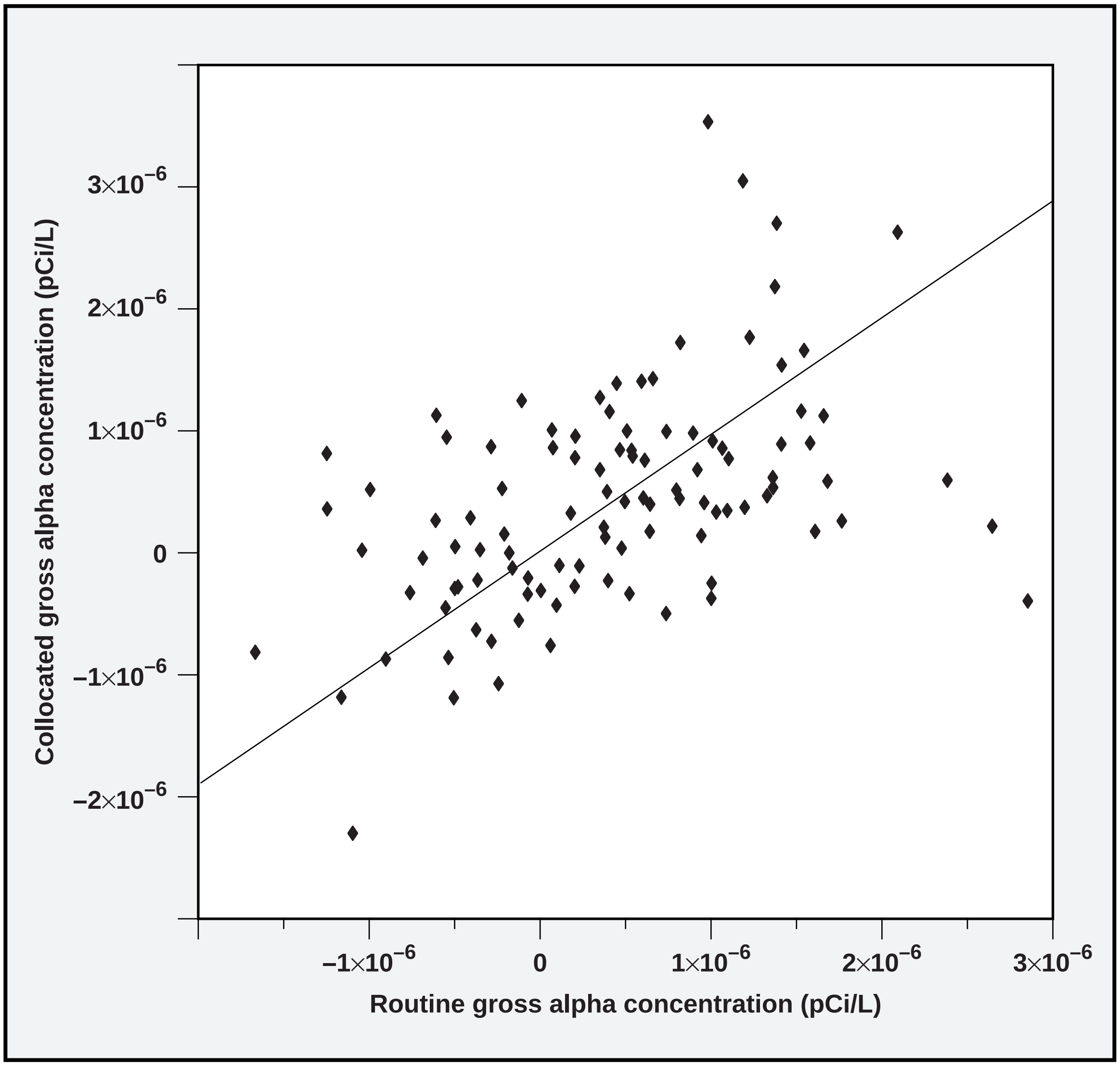

Figure 13-3. Gross alpha concentration from collected samples showing data with a lot of scatter.

continued access to the property could not be reached with the landowners. Location L-RRCH was replaced by L-CHUR, also on Vasco Road, north of LLNL. Location L-ALTA will be replaced by a new location, L-AMON, in 1998. Initiation of sampling at L-AMON was delayed due to difficulties associated with supplying power to that location. One location change was made to the Site 300 air particulate monitoring network prior to 1997—location 3-LIN was replaced by 3-PRIM. The new location better represents the sitewide maximally exposed individual and thus improves LLNL's ability to evaluate the dose to the public. In addition, off-road four-wheel drive access to 3-LIN was often denied for safety reasons; the new location should be more consistently available.

Table 13-4. Changes to environmental monitoring networks in 1997.

Environmental medium	Livermore site	Site 300
Air particulate	Abandoned location L-ALTA, 5/97; replaced location L-RRCH with location L-CHUR, 6/97	Replaced location 3-LIN with 3-PRIM prior to 1997
	Split into radiological air particulate and air particulate beryllium networks	Split into radiological air particulate and air particulate beryllium networks
Air tritium	Abandoned location L-ALTA, 5/97	Added location L-PRIM
Soil	Replaced location L-ALTA with L-AMON; replaced location L-RRCH with L-CHUR. Abandoned locations L-CAFE, L-ERCH.	No changes
Arroyo sediment	Added location L-ALPE	Not sampled
Vegetation	No changes	No changes
Wine	No changes	Not sampled
Rain	Added special study (on-site locations only)	No changes
Storm water runoff	Expanded pesticides monitoring, initiated special metals study	No changes
Drainage Retention Basin	No changes	Not sampled
Other surface water	Monthly pool sampling for tritium reduced to quarterly; eliminated pool sampling for lead	Not sampled
Ground water	Added several wells, W-204, W-363, W-119, W-906, W-1303, W-1308, W-594, W-593, W-007, W-226, W-306, and W-307, to monitor possible leachate from disposal sites.	No changes
Sewage	No changes	See WDR-248
WDR-248 Networks	Not applicable	No changes
Thermoluminescent dosimeters	Minor changes to three locations	No changes
Cooling towers	Not sampled	No changes

The air tritium network also abandoned location L-ALTA in 1997. This will be replaced by L-AMON in 1998. Routine air tritium monitoring at one Site 300 location was also performed for the first time in 1997 in response to the results of previously conducted special studies.

Minor location changes were also made to the soil and arroyo sediment monitoring networks in 1997. Soil sampling locations L-ALTA and L-RRCH were abandoned for the same reason air sampling was stopped there. Since electrical power is not required for soil sampling, these locations were replaced by L-AMON and L-CHUR in 1997. Soil sampling at locations L-CAFE and L-ERCH was also abandoned in 1997. L-ERCH could no longer be accessed due to difficulties in obtaining permission from the landowner; L-CAFE was dropped because of the unavailability of suitable soil for sampling at that location. Location L-ALPE was reinstated as part of the arroyo sediment network because it is a separate influent location to the Livermore site at which storm water runoff is also sampled. This location had been abandoned previously because the responsible environmental analyst was not aware it was a separate influent location.

Rain monitoring included special sampling of onsite locations for five storms in November. These additional storms were sampled because of an unexpectedly high value for tritium in an on-site runoff sample. Since storm water runoff cannot be resampled, expanded monitoring of subsequent storms is often used to validate or invalidate unexplained or unusual results.

Monitoring of storm water runoff was modified slightly in 1997 to specifically target pesticides used on site. Initially, these pesticides were only sampled at locations L-ASW and L-WPDC; monitoring was expanded to include the entire storm water runoff network based on the results of those samples. Metals analysis of storm water runoff was expanded to include both filtered and unfiltered samples beginning in November 1997. This source identification study will provide data that will enable us to determine what proportion of the metals detected in runoff is attributable to naturally occurring sediments and define the contributions of the aqueous and sediment fractions to the total reported values. This study will be completed in 1998 and a full discussion of the results will appear in the 1998 Annual Environmental Report.

In other surface water monitoring, sampling of the LLNL pool for tritium was reduced from monthly to quarterly and sampling of the pool for lead was eliminated after the second quarter. These reductions were made based upon a review of historical data.

Sampling locations for three Livermore Valley thermoluminescent dosimeters (TLDs) were changed slightly due to construction in the area. Sampling locations were moved from fences that had been removed to other nearby fences.

The LLNL environmental monitoring program uses alphanumeric location designator codes to define sampling locations. Tables 13-1 to 13-3 in Chapter 13 of the Data Supplement decode these sampling location designators and provide a cross-reference between current designators and those used in previous years. Changes made in 1997 are noted on those tables.

Explanation of Missing Samples

Planned samples and actual samples collected and analyzed in 1997 are summarized in **Table 13-5**. Air particulate sample loss was due to equipment failure, electrical problems, and access restrictions. Air tritium sample loss was due to a broken flask, equipment failure, electrical problems, and access restrictions. Missing arroyo sediment samples could not be taken because one sampling location was flooded with over four feet of water during the sampling period. Missing Livermore site rain samples were overlooked by the sampling technologist and not collected. Site 300 rain samples were not taken in February, April, and October due to lack of rainfall and are not counted as missing samples. Storm water runoff samples were missed at Site 300 because one location could not be accessed during the storm that was sampled and there was no flow at two other locations. The monthly Drainage Retention Basin (DRB) sample was not taken in August. Missing field measurements for dissolved oxygen and temperature in the DRB were due to equipment malfunction; several turbidity measurements in the DRB were not taken due to oversight by the sampling technologists. Analysis for radium-226 and radium-228 was omitted for five samples from the Livermore ground water network when the laboratory substituted a different analytical method for the one that was requested without consulting the environmental analyst. Two Site 300 ground water samples were inadvertently missed the remaining 131 missing samples were due to mechanical problems with pumps or barcads or access restriction due to construction in the area. Two planned samples from Livermore valley surface wells were not supplied and could not be analyzed. These wells are not sampled by LLNL directly making it difficult to consistently achieve 100% completeness for this network. Two daily sewage samples at Building 196 were lost in December due to equipment failure. In the WDR sewage ponds wastewater network, one sample and its duplicate were not analyzed because the analytical laboratory missed the holding time. Two TLDs from the Site 300 network and six from the Livermore networks disappeared during 1997, probably due to cows or vandalism. The remaining TLDs that were lost from the Livermore networks were due to construction in the area that led to the removal of fences and the attached TLDs; several sampling locations were permanently changed as a result. Five Site 300 cooling tower samples were inadvertently omitted due to technologist oversight.

Table 13-5. Sampling completeness in 1997, Livermore site and Site 300.

Environmental medium	Number of samples planned	Number of samples analyzed	Completeness (%)
Air particulate (Livermore)			
Radiological parameters	1224	1195	97.6
Beryllium	96	96	100
Air particulate (Site 300)			
Radiological parameters	672	665	99.0
Beryllium	60	60	100
Air tritium			
Livermore	528	524	99.2
Site 300	26	24	92.3
Soil			
Livermore	42	42	100
Site 300	30	30	100
Arroyo sediment (Livermore only)	32	28	87.5
Vegetation			
Livermore	32	32	100
Site 300	68	68	100
Wine	25	25	100
Rain			
Livermore	86	83	96.5
Site 300	4	4	100
Storm water runoff			
Livermore	367	367	100
Site 300	73	48	65.8
Drainage Retention Basin			
Field measurements	156	110	75.0
Samples	104	99	95.2
Other surface water (Livermore only)	64	64	100
Ground water			
Livermore	698	687	98.4
Site 300	3975	3842	96.6
Livermore Valley wells	26	24	92.3

Table 13-5. Sampling completeness in 1997, Livermore site and Site 300.

Environmental medium	Number of samples planned	Number of samples analyzed	Completeness (%)
Sewage			
B196	913	909	99.6
C196	374	374	100
LWRP effluent	128	128	100
Digester sludge	376	376	100
WDR-96-248			
Surface impoundments wastewater	69	69	100
Surface impoundments ground water	272	272	100
Sewage ponds wastewater	30	28	93.3
Sewage ponds ground water	120	120	100
Thermoluminescent dosimeters			
Livermore	172	157	91.3
Site 300	72	70	97.2
Cooling towers (Site 300 only)	84	79	94.0

Statistical Methods

Statistical methods used in this report have been implemented pursuant to the *Environmental Monitoring Plan* (Tate et al. 1995). These methods reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Data review and analyses are conducted in accordance with the *Environmental Monitoring Plan* and the Environmental Monitoring Section's Data Analysis Procedure. These documents contain detailed information regarding the acceptability of data and the procedures that are followed for the identification, notification, and correction of suspect data.

Radiological Data

The precision of radiological analytical results is displayed in the Data Supplement data tables as the 2σ counting error. The counting errors are not used in any summary statistic calculations. Any radiological result exhibiting a 2σ counting error greater than or equal to 100% is considered to be indistinguishable from zero. The reported concentration is derived from the number of sample counts minus the number of background counts. A sample with a low or zero concentration may therefore be reported to have a negative value; such results are reported in the tables and used in the calculation of summary statistics and statistical comparisons. Some analytical laboratory reports provide a minimum detectable activity rather than a reported value when the radiological result is below the detection criterion. In this case, the result is presented in the tables with a less-than symbol (<) to indicate its status.

Nonradiological Data

Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than symbol. The actual detection limit values are used in the calculation of summary statistics as explained below.

Statistical Comparisons

Standard comparison techniques (such as regression, t-tests, and analysis of variance) have been used where appropriate to determine the statistical significance of trends or differences between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word "significant" in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance and are based on professional judgment.

Summary Statistics

Determinations of measures of central tendency and associated measures of dispersion are calculated according to the *Environmental Monitoring Plan* (Tate et al. 1995). For data sets not containing values below the detection criterion, the measures of central tendency and dispersion are the median and interquartile range (IQR). The IQR is the range that encompasses the middle 50% of the data set. Radiological data sets that include values less than zero may have an IQR greater than the median.

For data sets with one or more, but fewer than one half, values below the detection criterion, the measure of central tendency is the median. If the values of the detection limits and the number of values below the detection limit permit (determined on a case-by-case basis), dispersion is reported as the IQR. Otherwise, no measure of dispersion is reported. Statistics are calculated using the reported detection limit value for nonradiological data or the reported value for radiological data.

For data sets with one half or more of the values below the detection criterion, the central tendency is reported as less than the median value. Dispersion is not reported.

Radiation Units

Data for 1997 have been reported in Système Internationale (SI) units to conform with standard scientific practices and federal law. Values in the text are reported in becquerels (Bq) and millisieverts (mSv); equivalent values in picocuries (pCi) and millirems (mrem) are given in parentheses.

Quality Assurance Process for the Environmental Report

Unlike the preceding discussion, which focused on standards of accuracy and precision in data acquisition and reporting, a discussion of quality assurance / quality control procedures for a technical publication per se, must deal with how to retain content accuracy through the publication process. Because publication of a large, data-rich document like this site annual *Environmental Report* involves many operations and many people, the chances for introducing errors are great. At the same time, ensuring quality is more difficult because a publication is less amenable to the statistical processes used in standard quality assurance methods.

The QA procedure we used concentrated on the tables and figures in the report and enlisted the chapter authors and participating analysts to check the accuracy of sections other than those they had authored. In 1997, the 75 illustrations and 68 tables in Volume 1 (now called the main volume) and the 121 tables in Volume 2 (now called the Data Supplement) were checked by 27 authors, contributors, and a few summer students. Checkers were assigned illustrations and tables and given a copy of each item they were to check along with a quality control form to fill out as they checked the item. Items to be checked included figure captions and table titles for clarity and accuracy, figure labels and table headings, units, significant figures, and consistency with text. When checking numerical data, checkers randomly selected 10% of the data and compared it to values in the master database. If all 10% agreed with the database, further checking was deemed unnecessary. If there was disagreement in the data, the checker compared another 10% of the data with the database values. If more errors were found, the checker had then to verify every piece of data in the table or illustration.

Completed quality control forms and the corrected illustrations or tables were returned to the report editors, who were responsible for ensuring that changes, with the agreement of the original contributor, were made. This quality assurance check resulted in over 100 changes being made to the draft document. These included corrections to numerical data in text and tables, slight adjustments to sampling locations on maps, corrections to footnotes in tables, and corrections to figure captions and table titles.

Appendix A
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Armstrong, D., L. Hall, J. Daniels, L. McDowell-Boyer, G. Gallegos, F. Gouvei, P. Tate, C. Stoker, and J. Shinn, *Data Supporting the 1995 Health Risk Assessment for the Hazardous and Mixed Waste Management Facilities at Lawrence Livermore National Laboratory,* Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-122091-97).

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Appendix B
Methods of Dose Calculations

Introduction

Radiological doses calculated from measured activities are a principal indicator of the potential impact of LLNL operations on surrounding populations. The doses from ingestion of water and locally produced foodstuff are based on actual measurements of radionuclide concentrations in the various media, determined by sampling, as described in Chapters 7 through 11. Data needed to evaluate potential doses from the inhalation and immersion pathways are provided by air surveillance monitoring, as described in Chapter 4.

The data on radionuclide concentrations or activities in these media are necessary inputs to the dose-rate equations described here. The examples presented below concern dose assessments for significant agricultural products of the Livermore Valley, including wine, and general vegetation, and in particular describe the forage-cow-milk pathway for ingestion of tritium in vegetation. The rate equations can also be used to estimate doses that would occur from ingestion of water at each of the Livermore Valley and Site 300 water sampling locations, though none of these is actually a primary source of drinking water.

Dose Calculation Methods

The dose calculation methods given here for the ingestion, inhalation, and immersion pathways are based on the NRC Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent* (U.S. Nuclear Regulatory Commission 1997). The dose and dose-rate conversion factors used in these calculations were obtained from the committed dose equivalent tables for DOE dose calculations and are consistent with those specified in *ICRP 30, Limits of Intakes of Radionuclides by Workers* (International Commission on Radiological Protection [ICRP] 1980).

The calculations use conventional activity units of picocuries (pCi) and dose units of millirem (mrem). The conversion constants that apply when converting to Système International (SI) activity units of becquerels (Bq) and dose units of sieverts (Sv) are:

1 pCi = (3.7×10^{-2}) Bq
1 mrem = (1×10^{-5}) Sv = 10 μSv = 1×10^{-2} mSv

The annual whole-body dose rate from ingestion of a particular food or drink is expressible as a product of three factors: the rate the food or drink is consumed (e.g., in L / y), the radionuclide concentration (e.g., in pCi / L) in the food or drink, and the dose rate conversion factor (e.g., in mrem / pCi) for the radionuclide. In the following subsections, equations of this type are used to estimate the annual dose from tritium in water and milk (directly consumed), from tritium ingested by humans via the forage-cow-milk pathway, and, more generally the annual dose from radionuclides in meat, liquids, and leafy vegetables. Similar formulas are given for the inhalation dose and immersion dose, with HTO and HT, respectively, used as specific examples.

Generally, the concentrations are measured, while the appropriate consumption-rate factors are taken from the literature. The water and milk consumption rates are estimated to be 730 L / y and 310 L / y, respectively, in Appendix 1 of the NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1997). In the absence of consumption data on locally produced wine, we employ the conservative (high dose) assumption that the intake rate for wine is the same as that for water. The resultant dose is expected to be several times too high for wine but well below levels of health concern.

LLNL's first use of these dose-rate formulas in our environmental annual reports is described by Silver et al. (1980).

Annual Dose from Potable Water

Based on the assumption that all water sampled is available as drinking water, the annual whole-body dose for tritium in mrem / y is calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem}/\text{y}) = C_{\text{w}} \times U_{\text{w}} \times D_{\text{w}} \qquad \text{(B-1)}$$

where

C_{w} = concentration of tritium in water (pCi / L)

U_{w} = water consumption rate (L / y) = 730 L / y for maximally exposed individual

D_{w} = dose conversion factor (mrem / pCi)

= 6.3×10^{-8} mrem / pCi for tritium for the whole-body ingestion pathway for an adult (similarly, for ^{40}K the dose conversion factor is 1.88×10^{-5} mrem / pCi, and for ^{137}Cs, it is 2.17×10^{-7} mrem / pCi)

$D_{\text{whole body}}$ = effective dose equivalent (mrem / y) from ingestion of 730 L of potable water with tritium concentration C_w.

Annual Dose from Forage-Cow-Milk Pathway for Tritium in Vegetation

Based on the assumption that all feed for the cattle was pasture grass, the effective dose equivalent per µCi / mL of tritiated water (HTO) for the maximally exposed individual is calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem / y}) = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \qquad \text{(B-2)}$$

where

D_{veg} = mrem / y dose from ingestion of vegetables

D_{meat} = mrem / y dose from ingestion of meat

D_{milk} = mrem / y dose from ingestion of milk.

Vegetation

$$D_{\text{veg(leafy)}} = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}} \qquad \text{(B-2a)}$$

where

U_{veg} = intake rate (kg / y): 64 kg / y for maximally exposed individual

C_{veg} = concentration (pCi / kg): $10^9 \dfrac{\text{pCi / kg}}{\mu\text{Ci / mL}} \times (C_{\text{veg}}\,[\mu\text{Ci / mL measured}])$

D_{HTO} = dose factor (mrem / pCi): 6.3×10^{-8} mrem / pCi for ^{3}H for the adult wholebody ingestion pathway.

The tritium dose from ingestion of vegetation is then

$$D_{\text{veg}}(\text{mrem / y}) = (0.40 \times 10^4) \times (C_{\text{veg}}\,[\mu\text{Ci / mL measured}]).$$

Note: In this and some of the following equations, the dimensions associated with a multiplicative factor are not shown explicitly; the dimensions of the dependent variable and measured quantity are shown explicitly. For example, the above factor (0.40×10^4) carries units of $\dfrac{(\text{mL} \bullet \text{mrem})}{(\text{y} \bullet \mu\text{Ci})}$.

Meat

$$D_{meat}(\text{mrem/y}) = U_{meat} \times C_{meat} \times D_{HTO} \qquad \text{(B-2b)}$$

where

U_{meat} = intake rate (kg/y): 110 kg/y for maximally exposed individual

C_{meat} = $(F_f) \times (Q_f) \times (C_{veg}) \times (e^{[-\lambda_i t_s]})$

D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^{3}H for the adult whole-body ingestion pathway

F_f = fraction of daily intake of nuclide per kilogram of animal/fish (pCi/kg in meat per pCi/d ingested by the animal) (d/kg): 1.2×10^{-2} d/kg

Q_f = amount of feed consumed (kg/d): 50 kg/d

C_{veg} = concentration (pCi/kg): $10^9 \dfrac{\text{pCi / kg}}{\mu\text{Ci / mL}} \times (C_{veg}\,[\mu\text{Ci/mL measured}])$

λ_i = radiological decay constant (d^{-1}): 1.5×10^{-4} d^{-1}

t_s = time between slaughter to consumption (d): 20 d

$$\begin{aligned} C_{meat} &= (1.2 \times 10^{-2}\ \text{d/kg}) \times (50\ \text{kg/d}) \times (C_{veg}\,[\mu\text{Ci/mL}]) \\ &\quad \times \left(10^9 \frac{\text{pCi / kg}}{\mu\text{Ci / mL}}\right) \times (\exp[\{-1.5 \times 10^{-4}\} \times \{20\}]) \\ &= 0.6 \times 10^9 \frac{\text{pCi / kg}}{\mu\text{Ci / mL}}) \times (C_{veg}\,[\mu\text{Ci/mL measured}]). \end{aligned}$$

The tritium dose rate from meat consumption is then

$$\begin{aligned} D_{meat}(\text{mrem/y}) &= (110\ \text{kg/y}) \times (0.6 \times 10^9\ \frac{\text{pCi / kg}}{\mu\text{Ci / mL}} \times C_{veg}\,[\mu\text{Ci/mL measured}]) \\ &\quad \times (6.3 \times 10^{-8}\ \text{mrem/pCi}) \\ &= (0.41 \times 10^4) \times (C_{veg}\,[\mu\text{Ci/mL measured}]). \end{aligned}$$

Milk

$$D_{milk}(\text{mrem/y}) = U_{milk} \times C_{milk} \times D_{HTO} \qquad \text{(B-2c)}$$

where

U_{milk} = intake rate (L / y): 310 L / y for maximally exposed individual

D_{HTO} = dose factor (mrem / pCi): 6.3×10^{-8} mrem / pCi for ^{3}H for the adult whole-body ingestion pathway

C_{milk} = $(F_m) \times (Q_f) \times (C_{\text{veg}}) \times (e^{[-\lambda_i t_f]})$

F_m = fraction of daily intake of nuclide per liter of milk (pCi / L in milk per pCi / d ingested by the animal) (d / L): 1.0×10^{-2} d / L

Q_f = amount of feed consumed by the animal (kg / d): 50 kg / d

C_{veg} = concentration (pCi / kg): $(10^9 \dfrac{\text{pCi / kg}}{\mu\text{Ci / mL}}) \times (C_{\text{veg}}\ [\mu\text{Ci / mL measured}])$

λ_i = radiological decay constant (d^{-1}): 1.5×10^{-4} d^{-1}

t_f = time from milking to milk consumption (d): 2 d

$$C_{\text{milk}} = (1.0 \times 10^{-2}\ \text{d / L}) \times (50\ \text{kg / d}) \times (C_{\text{veg}}\ [\mu\text{Ci / mL}]) \times (10^9 \frac{\text{pCi / kg}}{\mu\text{Ci / mL}}) \times (\exp[\{-1.5 \times 10^{-4}\} \times \{2\}])$$

$$= (0.5 \times 10^9 \frac{\text{pCi / kg}}{\mu\text{Ci / mL}}) \times (C_{\text{veg}}\ [\mu\text{Ci / mL measured}]).$$

The tritium dose rate from directly consumed milk is then

$$D_{\text{milk}}\ (\text{mrem / y}) = (310\ \text{L / y}) \times ([0.5 \times 10^9 \frac{\text{pCi / kg}}{\mu\text{Ci / mL}}] \times [C_{\text{veg}}\ \{\mu\text{Ci / mL measured}\}]) \times (6.3 \times 10^{-8}\ \text{mrem / pCi})$$

$$= (0.97 \times 10^4) \times (C_{\text{veg}}\ [\mu\text{Ci / mL measured}]).$$

Whole Body

$$D_{\text{whole body}}\ (\text{mrem / y}) = ([0.40 \times 10^4] \times [C_{\text{veg}}\ \{\mu\text{Ci / mL measured}\}]) + ([0.41 \times 10^4] \times [C_{\text{veg}}\ \{\mu\text{Ci / mL measured}\}]) + ([0.97 \times 10^4] \times [C_{\text{veg}}\ \{\mu\text{Ci / mL measured}\}]).$$

The total annual dose rate from the forage-cow-milk pathway for tritium in vegetation is then

$$D_{\text{whole body}}\ (\text{mrem / y}) = ([1.78 \times 10^4] \times [C_{\text{veg}}\ \{\mu\text{Ci / mL measured}\}]).$$

Inhalation/Immersion Dose

Doses due to inhalation of and immersion in radionuclide-contaminated air can be estimated in an analogous way to the preceding treatment of ingestion doses. The starting point is to evaluate the radionuclide concentration in air, χ (Ci/m^3) at the location of interest. χ can be directly measured, or calculated using a Gaussian dispersion air transport model. In the latter approach, the calculated quantity is the atmospheric dispersion parameter, χ /Q, which is the product of the radionuclide concentration in air χ(Ci/m^3) at all locations of interest and the source release rate Q(Ci/s).

For inhalation dose, once χ or the product (χ /Q) × (Q) is evaluated, it is multiplied by the inhalation rate of a human to obtain the number of curies of radioactive material inhaled by the human body. Dose and dose-rate conversion factors provided by the DOE (U.S. Department of Energy 1988), which are consistent with those specified in *ICRP 30* (International Commission on Radiological Protection 1980), are used to relate the intake of radioactive material into the body to dose commitment. These dose factors provide estimates of 50-year dose from a one-year intake of radioactivity.

The inhalation dose is expressible as

$$D_{\text{whole body}}(\text{mrem/y}) = U_{\text{inhalation}} \times C_{\text{radionuclide}} \times D_{\text{radionuclide}} \qquad \text{(B-3)}$$

where

$U_{\text{inhalation}}$ = air intake rate (L/y): 8,400 m^3/y for an adult

$D_{\text{radionuclide}}$ = dose conversion factor (mrem/pCi) for the radionuclide of interest (for HTO this factor is $1.5 \times 6.4 \times 10^{-8}$ mrem/pCi = 9.6 $\times 10^{-8}$ mrem/pCi for the adult whole body inhalation pathway, where the factor 1.5 accounts for absorption through the skin; for other radionuclides, see Table 2.1 in Eckerman et al. [1988])

$C_{\text{radionuclide}}$ = $(F) \times (\chi/\text{Q}) \times (\text{Q})$ = radionuclide concentration at the receptor (pCi/m^3)

$$F = \frac{1 \times 10^{12}\ \text{pCi / Ci}}{3.15 \times 10^{7}\ \text{s / y}} = 3.17 \times 10^{4}\ (\text{pCi/Ci})/(\text{s/y})$$

Q = radionuclide release rate (Ci/y)

χ/Q = diffusion parameter (s/m^3); calculated.

The wholebody inhalation dose rate is then

$$D_{\text{whole body}}(\text{mrem/y}) = (3.17\times10^4\,[\text{pCi/Ci}]/[\text{s/y}])\times(\chi/\text{Q})(\text{s/m}^3)\times(\text{Q}[\text{Ci/y}])$$
$$\times(8.4\times10^3\ \text{m}^3/\text{y})\times D_{\text{radionuclide}}\,(\text{mrem/pCi}).$$

The immersion dose is similarly expressible as

$$D_{\text{whole body}}(\text{mrem/y}) = C_{\text{radionuclide}}\times(DRF) \tag{B-4}$$

where

$C_{\text{radionuclide}}$ = $(F)\times(\chi/\text{Q})\times(\text{Q})$ = radionuclide concentration at the receptor (pCi/m^3)

F = $\dfrac{1\times10^{12}\ \text{pCi / Ci}}{3.15\times10^{7}\ \text{s / y}} = 3.17\times10^4\ (\text{pCi/Ci})/(\text{s/y})$

Q = radionuclide release rate (Ci / y)

χ/Q = diffusion parameter (s/m^3), calculated

DRF = the external dose-equivalent rate factor per unit radionuclide concentration $(\text{mrem/y})/(\text{pCi/m}^3)$ [for elemental ^{3}H this factor DRF is $3.9\times10^{-8}\,(\text{mrem/y})/(\text{pCi/m}^3)$; for the short-lived isotopes ^{13}N and ^{15}O it equals $5.1\times10^{-3}\,(\text{mrem/y})/(\text{pCi/m}^3)$; for other radionuclides see Table 2.3 in Eckerman et al. (1988).

Appendix C. Reports for Regulatory Agencies

Title	Agency	Frequency
AB2588 Emissions Report	Bay Area Air Quality Management District San Joaquin Valley Unified Air Pollution Control District	Biennial
Air Emission Permit Renewals and Emissions Report	Bay Area Air Quality Management District San Joaquin Valley Unified Air Pollution Control District	Yearly
Quarterly Solvent Usage	Bay Area Air Quality Management District	Quarterly
Recycling Unit Contingency/Business Plans	Department of Toxic Substances Control	As required
Conditional Exemption Unit Contingency Plans	Department of Toxic Substances Control	As required
PCB Annual Report	Environmental Protection Agency	Yearly
Medical Waste Permit	Alameda County Emergency Health Services and Department of Public Health Services, San Joaquin County	As required
Explosive Waste Treatment Facility—Site 300 Permit	Department of Toxic Substances Control	Every 10 years
Main Site Part A&B Hazardous Waste Permit Application (includes contingency plans and closure plans)	Department of Toxic Substances Control	As required
Site 300 Container Storage Area (B883) and Explosive Waste Storage Facility Permit	Department of Toxic Substances Control	Every 10 years
Cultural Resource Management Plan	Department of Energy California State Historic Preservation Officer	As required
RCRA Section 3016 Report, Inventory of Federal Agency Hazardous Waste Facilities	Department of Energy Environmental Protection Agency	As required
Less-than-90-Day Waste Accumulation Area Contingency Plans	Department of Toxic Substances Control	As required
SB14 Documentation Plan	California Environmental Protection Agency	Every 4 years
Ozone Depleting Chemicals Phase Out Report	Department of Energy Environmental Protection Agency	Upon request
DOE Annual Waste Minimization Report	Department of Energy	Yearly

Title	Agency	Frequency
Waste Minimization Certification for Site 300	Department of Toxic Substances Control	Yearly
Monthly NEPA Report	Department of Energy under NEPA	Monthly
NEPA Reviews, Proposed LLNL/Department of Energy Projects	Department of Energy	As required
CEQA Review for Department of Energy/UC Contract Renewal	University of California	As required
CEQA Reviews, Proposed LLNL/UC Projects	University of California	As required
Spill Prevention Control and Countermeasures Plans (Livermore Site and Site 300) Plan	Environmental Protection Agency San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	Every 3 years or when there are significant changes
Closure Plans for any hazardous waste/product underground storage tanks (UST) removed from service	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Closure Report for any hazardous waste/product UST removed from service	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Monitoring Program for any hazardous waste/ product UST (underground storage tank) removed from service	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Closure Reports for greater than 90-day hazardous waste AST (aboveground storage tank) operated under Interim Status or a Permit and removed from service	Department of Toxic Substances Control	As required
Engineering Assessments for RCRA hazardous waste tanks	Environmental Protection Agency	As required
Installation Plans for new hazardous waste/product UST	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Hazardous Waste/Product UST Operating Permit	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	Yearly
Less-than-90-Day Hazardous Waste Tank Contingency Plans (for Permitted Underground Tank Systems at Livermore Site)	Department of Toxic Substances Control	As required
Tank Operating Plans	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Tank Monitoring Program for Hazardous Waste UST	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	Prior to new tank use

Title	Agency	Frequency
Tank Modification/Approval Plan	Alameda County Emergency Health Services or Department of Public Health Services, San Joaquin County	As required
Monthly Sewer Monitoring Report	Livermore Water Reclamation Plant	Monthly
Site 300 Pit 1 and 7 Compliance Monitoring Reports	Central Valley Regional Water Quality Control Board Environmental Protection Agency Department of Toxic Substances Control	Quarterly and yearly
Site 300 Quarterly Cooling Tower Discharge Report	Central Valley Regional Water Quality Control Board	Quarterly
Wastewater Point-Source Monitoring Semi-Annual Report	Livermore Water Reclamation Plant	Twice a year
Storm Water Pollution Prevention Plans (Livermore Site and Site 300)	San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	As required
Storm Water Pollution Prevention Plans for Construction (Livermore Site and Site 300)	San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	As required
Ground Water Protection Management Program	Department of Energy	Every 3 years or as required
Storm Water Monitoring Programs (Livermore Site and Site 300)	San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	As required
Industrial Storm Water Discharge Annual Reports (Livermore Site and Site 300) and Site 300 Cooling Tower Annual Report	San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	Yearly
Storm Water Pollution Prevention Annual Certifications for Construction Projects (Livermore Site and Site 300)	San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board	yearly
Quarterly and Annual Compliance Reports for Explosive Process Area Surface Impoundments, Sewage Evaporation and Percolation Ponds, and Percolation Pits	Central Valley Regional Water Quality Control Board	Quarterly and yearly
DRB Quarterly/Annual Monitoring Reports	CERCLA	Quarterly and yearly
Hazardous Material Business Plan and Chemical Inventory	Alameda County Health Care Services Agency or San Joaquin County Office of Emergency Services	Yearly
SARA 313/Toxic Release Inventory	Department of Energy/State and Federal EPA	Yearly
Beryllium Ambient Monitoring	Bay Area Air Quality Management District	Quarterly
NESHAPs Annual Report	Environmental Protection Agency	Yearly

Title	Agency	Frequency
Environmental Monitoring Plan	Department of Energy	Every three years
Site Annual Environmental Report	Department of Energy	Yearly
Site 300 Pits 1 and 7 Landfill Closure Caps Inspection/Monitoring Independent Engineering Evaluation	Department of Toxic Substances Control Central Valley Regional Water Quality Control Board Environmental Protection Agency	Yearly
Biennial Hazardous Waste Report	Department of Toxic Substances Control (under Environmental Protection Agency delegated authority)	Every 2 years
Annual Hazardous Waste Report	Department of Toxic Substances Control	Yearly
Conceptual Site Treatment Plan (CSTP) Draft Site Treatment Plan (DSTP) Final Site Treatment Plan (FSTP)	Department of Toxic Substances Control Environmental Protection Agency Department of Energy	As required
Safety Analysis Report	Department of Energy	As required
Contingency Plans	Department of Toxic Substances Control	As required
Closure Plans	Department of Toxic Substances Control	As required
EIR Mitigation Monitoring Annual Report	University of California	Yearly
FFA–CERCLA Reports	Environmental Protection Agency Department of Toxic Substances Control San Francisco Bay Regional Water Quality Control Board Central Valley Regional Water Quality Control Board Department of Energy/EM-40	As required

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Glossary

Acronyms and Abbreviations

A	ACEHS	Alameda County Environmental Health Services.
	ACG	Ambient concentration guide.
	ACMT	Analytical Contract Management Team.
	ACOE	Army Corps of Engineers.
	ALARA	As low as reasonably achievable.
	ANOVA	Analysis of variance (see Technical Terms).
	ANSI	American National Standards Institute.
	ARB	Air Resources Board.
	ASME	American Society of Mechanical Engineers.
	AST	Aboveground storage tank.
	ATA	Advanced Test Accelerator.
	ATSDR	Agency for Toxic Substances and Disease Registry.
	AWQC	Ambient water quality criteria.
B	BAAQMD	Bay Area Air Quality Management District. The local agency responsible for regulating stationary air emission sources (including the LLNL Livermore site) in the San Francisco Bay Area.
	BAT	Best available technology.
	BETX (or BTEX)	Benzene, ethyl benzene, toluene, and xylene.
	BMP	Best management practice.
	BOD	Biochemical oxygen demand.
	Bq	Becquerel (see Technical Terms).
C	Cal/EPA	California Environmental Protection Agency.
	CAM	Continuous air monitor.
	CAP88-PC	Computer code required by the EPA for modeling air emissions of radionuclides.

CAREs	(Tri-Valley) Citizens Against a Radioactive Environment.
CCR	California Code of Regulations. Codification of regulations promulgated by the State of California.
CDFG	California Department of Fish and Game.
CEPRC	Chemical Emergency Planning and Response Commission.
CEQA	California Environmental Quality Act of 1970. CEQA requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions.
CERCLA / SARA	Comprehensive Environmental Response, Compensation and Liability Act of 1980. Administered by EPA, this program, also known as Superfund, requires private parties to notify the EPA after the release of hazardous substances and undertake short-term removal and long-term remediation. If conditions exist that could create the threat of hazardous substances being released, the Act also requires the remediation of those conditions. In 1986, the Superfund Amendments and Reauthorization Act (SARA) was enacted, which amended and reauthorized CERCLA for five years at a total funding level of $8.5 billion.
CES	Chemistry and Materials Science Environmental Services. An LLNL laboratory that analyzes environmental samples.
CFC	Chlorofluorocarbon (see Technical Terms).
CFF	Contained Firing Facility.
CFR	Code of Federal Regulations. A codification of all regulations promulgated by federal government agencies.
ChemTrack	Computerized chemical inventory and tracking system.
CHP	California Highway Patrol.
Ci	Curie (see Technical Terms).
COC	Constituent of concern.
CRMP	Cultural Resource Management Plan.
CRWQCB	California Regional Water Quality Control Board.
CVRWQCB	Central Valley Regional Water Quality Control Board.
CWA	Clean Water Act.
CWG	Community Work Group.

D	DCG	Derived Concentration Guide (see Technical Terms).
	DEHP	Bis(2-ethylhexyl)phthalate.
	DfE	Design for Environment.
	DEP	Diethylphthalate.
	DHS	California Department of Health Services.
	DLM	Designated level methodology.
	DO	Dissolved oxygen.
	DoD	U.S. Department of Defense.
	DOE	U.S. Department of Energy. The federal agency that is responsible for conducting energy research and regulating nuclear materials used for weapons production.
	DOI	U.S. Department of the Interior
	DOT	U.S. Department of Transportation.
	DRB	Drainage Retention Basin. Man-made, lined pond used to capture storm water runoff and treated water at the LLNL Livermore site.
	DTSC	California Environmental Protection Agency, Department of Toxic Substances Control.
	DWTF	Decontamination and Waste Treatment Facility.
E	EA	Environmental Assessment. An environmental review document that identifies environmental impacts from any federally approved or funded project. If an EA shows significant impact, an EIS is required.
	EDE	Effective dose equivalent (see Technical Terms).
	EDO	Environmental Duty Officer.
	EEA	Environmental and Exposure Assessment.
	EE/CA	Engineering evaluation/cost analysis.
	EFA	East Firing Area (LLNL Site 300).
	EIR	Environmental Impact Report. A detailed report prepared pursuant to CEQA on the environmental impacts from any action carried out, approved, or funded by a California state, regional, or local agency.

	EIS	Environmental Impact Statement. A detailed report, required by the National Environmental Policy Act, on the environmental impacts from a federally approved or funded project. An EIS must be prepared by a federal agency when a “major” federal action that will have “significant” environmental impacts is planned.
	EML	U.S. Department of Energy Environmental Measurements Laboratory.
	EMRL	Environmental Monitoring Radiation Laboratory.
	EMSL	Environmental Monitoring Systems Laboratory.
	EO	Executive Order.
	EOG	Environmental Operations Group.
	EPA	U.S. Environmental Protection Agency. The federal agency responsible for enforcing federal environmental laws. Although some of this responsibility may be delegated to state and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment.
	EPCRA	Emergency Planning and Community Right-to-Know Act of 1986. EPCRA requires facilities that produce, use, or store hazardous substances to report releases of reportable quantities or hazardous substances to the environment.
	EPD	Environmental Protection Department (LLNL).
	EPL	Effluent pollutant limit.
	ERD	Environmental Restoration Division of the Environmental Protection Department at LLNL.
	ES&H	Environmental, Safety, and Health.
	ESD	Explanation of significant differences.
	EST	Environmental Support Team.
	EWSF	Explosives Waste Storage Facility.
	EWTF	Explosives Waste Treatment Facility.
F	FFA	Federal facility agreement. A negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, RWQCB, and DOE).
	FHC	Fuel hydrocarbon.

	FONSI	Finding of no significant impact.
	Freon 113	1,1,2-trichloro-1,2,2-trifluoroethane.
G	g	Gram. The standard metric measure of weight approximately equal to 0.035 ounce.
	GAC	Granulated activated carbon.
	GBq	Gigabecquerel. 1×10^9 Becquerel.
	GFI	Ground fault interrupt.
	GSA	General Services Area (LLNL Site 300).
	GWP	Ground Water Project.
	GWPMP	Ground Water Project Management Program.
	GWTF	Ground water treatment facility.
	GWTS	Ground water treatment system.
	Gy	Gray. The SI unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray equals 100 rads, or one joule per kilogram. (See “Gray” in Technical Terms.)
H	HCAL	Hazards Control Department Analytical Laboratory.
	HCD	Hazards Control Department.
	HDPE	High-density polyethylene.
	HE	High explosives. Materials that release large amounts of chemical energy when detonated.
	HEPA	High-efficiency particulate air (filter).
	HMX	Cyclotetramethyltetramine, a high-explosive compound. Also referred to as octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
	HPGe	High-purity germanium.
	HSD	(Tukey-Kramer) honestly significant difference (test).
	HSU	Hydrostratigraphic unit.
	HT	Tritiated hydrogen gas. Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 years.

	HTO	Tritiated water and water vapor (see HT).
	HWCA	California Hazardous Waste Control Act. This legislation specifies requirements for the management of hazardous wastes in California.
	HWM	Hazardous Waste Management Division of the Environmental Protection Department at LLNL.
I	ICRP	International Commission on Radiological Protection. An international organization that studies radiation, including its measurement and effects.
	IQR	Interquartile range (see Technical Terms).
	ISD	Interim status document.
	ISMS	Integrated safety management system.
	ISO	International Standards Organization.
J	JON	Judgment of Need.
L	LARPD	Livermore Area Recreation and Park District.
	LBNL	Lawrence Berkeley National Laboratory.
	LCRS	Leachate collection and removal system.
	LEPC	Local Emergency Planning Committee.
	LINAC	Linear accelerator.
	LLNL	Lawrence Livermore National Laboratory.
	LOC	Letter of concern.
	LOEC	Lowest observed effect concentration.
	LOS	Limit of sensitivity (detectability).
	LUFT	Leaking underground fuel tank.
	LWRP	Livermore Water Reclamation Plant. The City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.
M	MAL	Management action level.
	MCL	Maximum contaminant level in drinking water established by EPA or DTSC.
	MDC	Minimum detectable concentration.
	MDL	Minimum detection limit.

	MEI	Maximally exposed individual member of the public.
	MFP	Mixed fission products.
	ML	Megaliter. 10^6 liters.
	mL	Milliliter. 10^{-3} liter = 1 cm^3.
	MOLE	Miniature Optical Lair Explorer.
	mR	Milliroentgen. 10^{-3} roentgen.
	mrem	Millirem. 10^{-3} rem.
	MRP	Monitoring and Reporting Program
	MSDS	Material Safety Data Sheet.
	mSv	Millisievert. 10^{-3} sievert.
	MTBE	Methyl tertiary-butyl ether.
N	NBZ	North Buffer Zone (LLNL Livermore site).
	NCR	Nonconformance Report.
	NCRP	National Council on Radiation Protection.
	NEPA	National Environmental Policy Act. This federal legislation, enacted in 1969, requires all federal agencies to document and consider environmental impacts from federally funded or approved projects. DOE is responsible for NEPA compliance at LLNL.
	NESHAPs	National Emission Standards for Hazardous Air Pollutants. These standards are found in the Clean Air Act and set limits for hazardous air pollutants.
	NHPA	National Historical Preservation Act.
	NIF	National Ignition Facility.
	NIST	National Institute for Standards and Technology. The federal agency, formerly known as the National Bureau of Standards, responsible for reference materials against which laboratory materials are calibrated.
	NOEC	No observed effect concentration.
	NOI	Notice of Intent.
	NOV	Notice of Violation.

	NPDES	National Pollutant Discharge Elimination System. This federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways.
	NPL	National Priorities List.
	NRC	Nuclear Regulatory Commission. The federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense.
O	OBT	Organically bound tritium.
	ORAD	Operations and Regulatory Affairs Division of the Environmental Protection Department at LLNL.
	OSHA	Occupational Safety and Health Act.
	OSP	Operational Safety Procedure.
	OU	Operable Unit.
	PA	Programmatic Agreement.
P	PAAA	Price-Anderson Amendments Act.
	P2	Pollution Prevention.
	PCB	Polychlorinated biphenyl.
	PCE	Tetrachloroethene (or perchloroethylene).
	pCi	Picocurie. 1×10^{-12} Ci.
	PeerRP	Peer Review Panel.
	PEIS	Programmatic Environmental Impact Statement.
	%RSD	Percent relative standard deviation, a measure of precision.
	PHA	Public Health Assessment.
	PM	Performance measure.
	PMCL	Primary maximum contaminant level.
	PM-10	Fine particulate matter with an aerodynamic diameter equal to or less than 10 μm.
	ppb	Parts per billion. A unit of measure for the concentration of a substance in its surrounding medium. For example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion.

	PPG	Pollution Prevention Group of Environmental Protection Department at LLNL.
	ppm	Parts per million. A unit of measure for the concentration of a substance in its surrounding medium. For example, one million grams of water containing one gram of salt has a salt concentration of one part per million.
	PPOA	Pollution Prevention Opportunity Assessment.
	PRG	Preliminary remediation goal.
	PTU	Portable treatment unit.
Q	QA	Quality assurance.
	QC	Quality control.
R	R	Roentgen, (see Technical Terms).
	RAIP	Remedial Action Implementation Plan.
	RCRA	Resource Conservation and Recovery Act of 1976. RCRA is a program of federal laws and regulations that govern the management of hazardous wastes. RCRA is applicable to all entities that manage hazardous wastes.
	RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine, a high-explosive compound.
	RL	Reporting limit.
	RML	Radiological Measurements Laboratory.
	RMMA	Radioactive Materials Management Area.
	ROD	Record of Decision.
	ROI	Return on investment.
	ROWD	Report of Waste Discharge.
	RSD	Relative standard deviation.
	RWQCB	Regional Water Quality Control Board. The California regional agency responsible for water quality standards and the enforcement of state water quality laws within its jurisdiction. California is divided into a number of RWQCBs; the Livermore site is regulated by the San Francisco Bay Region, and Site 300 is regulated by the Central Valley Region.
S	SARA	Superfund Amendment and Reauthorization Act of 1986 (see CERCLA/SARA).
	SDWA	Safe Drinking Water Act.

SERC	State Emergency Response Commission.
SHPO	California State Historic Preservation Office.
SI	Système International d'Unités. An international system of physical units. Units of measure in this system include meters (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).
Site 300	LLNL's Experimental Test Site, located approximately 24 km east of the Livermore site.
SJCHD	San Joaquin County Health District. The local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.
SJCPHS	San Joaquin County Public Health Services.
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District. The local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County.
SL	Statistical limit.
SMCL	Secondary maximum contaminant level.
SME	Safety Management
SNL/California	Sandia National Laboratories, California.
SOP	Standard operating procedure.
SOV	Summary of violations.
SPCC	Spill Prevention Control and Countermeasures (Plans).
SSM	Stockpile Stewardship and Management.
STAR	Sample tracking and receiving (computer system).
STLC	Soluble threshold limit concentration. A value that can be used to determine if a waste is hazardous.
STP	Site Treatment Plan.
Sv	Sievert. (See Technical Terms.)
SVE	Soil vapor extraction.
SWDA	State Water Drinking Act.
SW-MEI	Sitewide maximally exposed individual member of the public.

	SWPPP	Storm Water Pollution Prevention Plan.
	SWRCB	California State Water Resources Control Board.
	SWRI	(LLNL) Site-wide Remedial Investigation (Report).
T	TBOS	Tetrabutyl orthosilicate.
	TBq	Terabecquerel. 1×10^{12} Becquerel.
	TCE	Trichloroethene.
	TCLP	Toxicity Characteristic Leaching Procedure.
	TDS	Total dissolved solids. The portion of solid material in a waste stream that is dissolved and passed through a filter.
	TF	Treatment facility.
	THM	Trihalomethane.
	TLD	Thermoluminescent dosimeter. A device used to measure external beta or gamma radiation levels. TLDs contain a material that after exposure to beta or gamma radiation emits light when processed and heated.
	TNT	Trinitrotoluene.
	TOC	Total organic carbon. The sum of the organic material present in a sample.
	TOX	Total organic halides. The sum of the organic halides present in a sample.
	TRI	Toxic Release Inventory.
	TRU	Transuranic waste.
	TSDF	Treatment, storage, and disposal facility.
	TSS	Total suspended solids.
	TTLC	Total threshold limit concentration. A value that can be used to determine if a waste is hazardous.
	TWMS	Total Waste Management System.
U	UC	University of California.
	USEPA	U.S. Environmental Protection Agency.
	USFWS	U.S. Fish and Wildlife Service.
	UST	Underground storage tank.

V	VOC	Volatile organic compound. Liquid or solid organic compounds that have a high vapor pressure at normal pressures and temperatures and thus tend to spontaneously pass into the vapor state.
	VPP	Voluntary Protection Program.
W	WAA	Waste accumulation area. An officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Hazardous Waste Management Division for off-site disposal.
	WDR	Waste Discharge Requirements. Issued by the California Regional Water Quality Control Board.
	WFA	West Firing Area (LLNL Site 300).
	WQO	Water quality objective.
	WSS	Work Smart Standards.
	WTF	Working Task Force.
Z	Zone 7	Alameda County Flood Control and Conservation District, Zone 7.

Technical Terms

A	Absorbed dose	The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The absorbed dose is expressed in units of rad or gray (l rad = 0.01 gray).
	Accuracy	The closeness of the result of a measurement to the true value of the quantity measured.
	Action Level	Defined by regulatory agencies, it is the level of pollutants which, if exceeded, requires regulatory action.
	Aerosol	A gaseous suspension of very small particles of liquid or solid.
	Alluvium	Sediment deposited by flowing water.
	Alpha particle	A positively charged particle emitted from the nucleus of an atom, having mass and charge equal to those of a helium nucleus (two protons and two neutrons).
	Ambient air	The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.

	Analyte	A constituent that is being analyzed.
	Anion	A negatively charged ion, for example Cl^-.
	ANOVA	Analysis of variance. A test of whether two or more sample means are statistically different.
	Aquifer	A saturated layer of rock or soil below the ground surface that can supply usable quantities of ground water to wells and springs. Aquifers can be a source of water for domestic, agricultural, and industrial uses.
	Aquitard	Low-permeability bed that bounds an aquifer.
	Atom	The smallest particle of an element capable of entering into a chemical reaction.
	Atomic absorption spectroscopy	Abbreviated AA. A method used to determine the elemental composition of a sample. In this method, the sample is vaporized and its light absorbance measured.
B	Barcad	Device that samples water in a well. Water, collected in a discrete water bearing zone, is forced to the surface by pressurized nitrogen.
	Becquerel (Bq)	The SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.
	Beta particle	A negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron.
	Biochemical (biological) oxygen demand	A measure of the amount of dissolved oxygen that microorganisms need to break down organic matter in water. It is used as an indicator of water quality.
C	Categorical discharge	Discharge from a process regulated by EPA rules for specific industrial categories.
	CFC	Chlorofluorocarbon. A compound that has fluorine and chlorine atoms on a carbon backbone. Freons are common CFCs.
	Chain-of-custody	A method for documenting the history and possession of a sample from the time of its collection, through its analysis and data reporting, to its final disposition.
	Chlorocarbon	A compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethene.

	Collective dose equivalent and collective effective dose equivalent	The sums of the dose equivalents or effective dose equivalents to all individuals in an exposed population within 80 km (50 miles) of the radiation source. These are evaluated by multiplying the dose received by an individual at each location by the number of individuals receiving that dose, and summing over all such products for locations within 80 km of the source. They are expressed in units of person-rem or person-sievert. The collective EDE is also referred to as the “population dose.”
	Committed dose equivalent	The predicted total dose equivalent to a tissue or organ over a 50-year period after an intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert; 100 rem equals one sievert).
	Committed effective dose equivalent	The sum of the committed dose equivalents to various tissues in the body, each multiplied by an appropriate weighting factor representing the relative vulnerability of different parts of the body to radiation. Committed effective dose equivalent is expressed in units of rem or sievert.
	Cosmic radiation	Radiation with very high energies, originating outside the earth’s atmosphere. Cosmic radiation is one source contributing to natural background radiation.
	Curie	A unit of measurement of radioactivity, defined as the amount of radioactive material in which the decay rate is 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute; one Ci is approximately equal to the decay rate of one gram of pure radium.
D	Daughter nuclide	A nuclide formed by the radioactive decay of another nuclide, which is called the parent.
	Depleted uranium	Uranium having a lower proportion of the isotope ^{235}U than is found in naturally occurring uranium; the fractions of ^{238}U, ^{234}U, and ^{235}U that we use for depleted uranium are defined in Supplement 12-3. Depleted uranium is sometimes referred to as D-38.
	DCG	Derived Concentration Guide. Concentrations of radionuclides in water and air that could be continuously consumed or inhaled for one year and not exceed the DOE primary radiation standard to the public (100 mrem / y EDE).

	De minimis	Shortened form of “de minimis non curat lex,” which means, “The law does not care for, or take notice of, very small or trifling matters.” A “de minimis level” would be a level that is so inconsequential that, by definition, it cannot be cause for concern.
	Dose	The energy imparted to matter by ionizing radiation; the unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.
	Dose commitment	The dose which an organ or tissue would receive during a specified period of time (e.g., 50 or 70 years) as a result of one year’s intake of one or more radionuclides.
	Dose equivalent	The product of absorbed dose in rad (or gray) in tissue and a quality factor representing the relative damage caused to living tissue by different kinds of radiation, and perhaps other modifying factors representing the distribution of radiation, etc. Dose equivalent is expressed in units of rem or sievert (l rem = 0.01 sievert).
	Dosimeter	A portable detection device for measuring the total accumulated exposure to ionizing radiation.
	Dosimetry	The theory and application of the principles and techniques of measuring and recording radiation doses.
	Downgradient	In the direction of ground water flow from a designated area; analogous to downstream.
E	Effective dose equivalent (EDE)	An estimate of the total risk of potential effects from radiation exposure. It is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the decimal fraction of the risk arising from irradiation of a selected tissue to the total risk when the whole body is irradiated uniformly to the same dose equivalent. These factors permit dose equivalents from nonuniform exposure of the body to be expressed in terms of an effective dose equivalent that is numerically equal to the dose from a uniform exposure of the whole body that entails the same risk as the internal exposure (ICRP 1980). The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent due to penetrating radiation from sources external to the body, and is expressed in units of rem (or sievert).
	Effluent	A liquid or gaseous waste discharged to the environment.

	Evapotranspiration	A process by which water is transferred from the soil to the air by plants that take the water up through their roots and release it through their leaves and other aboveground tissue.
F	Federal facility	A facility that is owned or operated by the federal government. Federal facilities are subject to the same requirements as other responsible parties once placed on the Superfund National Priorities List.
	Federal Register	A document published daily by the federal government containing notification of government agency actions. The Federal Register contains notification of EPA and DOE actions, including notification of EPA and DOE decisions concerning permit applications and rule-making.
G	Gamma ray	High-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies the emission of alpha or beta particles.
	Gray	The SI unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray equals 100 rads, or 1 joule per kilogram.
	Ground water	All subsurface water.
H	Half-life (radiological)	The time required for one-half the radioactive atoms in a given amount of material to decay. After one half-life, half of the atoms will have decayed; after two half-lives, three-fourths; after three half-lives, seven-eighths; and so on, exponentially.
	Hazardous waste	Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). In addition, EPA has listed as hazardous other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term more generally refers to any waste that EPA believes could pose a threat to human health and the environment if managed improperly.
	Hydraulic gradient	In an aquifer, the rate of change of total head (water-level elevation) per unit distance of flow at a given point and in a given direction.
	Hydrology	The science dealing with the properties, distribution, and circulation of natural water systems.
I	Inorganic compounds	Compounds that either do not contain carbon or do not contain hydrogen along with carbon. Inorganic compounds include metals, salts, and various carbon oxides (e.g., carbon monoxide and carbon dioxide).

	In situ	A term that can be used to refer to the treatment of contaminated areas in place, i.e., without excavation or other removal, as in the in situ treatment of soils through biodegradation of contaminants on site.
	Interim status	A legal classification that applies to hazardous waste incinerators or other hazardous waste management facilities that were under construction or in operation by November 19, 1980, and can meet other interim status requirements. Interim status facilities may operate while EPA considers their permit application.
	IQR	Interquartile range. The distance between the top of the lower quartile and the bottom of the upper quartile. The IQR provides a measure of the spread of data.
	Isotopes	Forms of an element having the same number of protons in their nuclei, but differing numbers of neutrons.
L	Liter	The SI measure of capacity approximately equal to 1.057 quart.
	Less than detection limits	A phrase indicating that a chemical constituent was either not identified or not quantified at the lowest level of sensitivity of the analytical method being employed by the laboratory. Therefore, the chemical constituent either is not present in the sample, or it is present in such a small concentration that it cannot be measured by the analytical procedure.
	Low-level waste	Waste defined by DOE Order 5820.2A. Low-level waste contains transuranic nuclide concentrations less than 100 nCi/g.
	Lower limit of detection	The smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.
	Lysimeter	An instrument for measuring the water percolating through soils and determining the dissolved materials.
M	Maximally Exposed Individual	The maximally exposed individual is a hypothetical member of the public at a fixed location who, over an entire year, receives the maximum effective dose equivalent (summed over all pathways) from a given source of radionuclide releases to air. Generally, the MEI is different for each source at a site.
	Multiple completion	A borehole with water surveillance monitoring devices (Barcads) placed at various levels and separated by impermeable layers of material such as grout. Usually the uppermost "completion" is accessible from the surface, making physical sample-taking possible (as opposed to Barcads), and is referred to as a well.

	Mixed waste	Waste that has the properties of both hazardous and radioactive waste.
N	Nonpoint source	Any nonconfined area from which pollutants are discharged into a body of water (e.g., agricultural runoff, construction runoff, and parking lot drainage), or into air (e.g., a pile of uranium tailings).
	Nuclide	A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable length of time.
O	Off-site	Outside the boundaries of the LLNL Livermore site and Site 300 properties.
	On-site	Within the boundaries of the LLNL Livermore site or Site 300 properties.
P	Part B permit	The second, narrative section submitted by generators in the RCRA permitting process. It covers in detail the procedures followed at a facility to protect human health and the environment.
	Perched aquifer	Aquifer that is separated from another water-bearing stratum by an impermeable layer.
	Performance standards (incinerators)	Specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in incinerator emissions.
	pH	A measure of hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6; basic solutions have a pH greater than 7; and neutral solutions have a pH of 7.
	Piezometer	Instrument for measuring fluid pressure. Generally used to measure the elevation of the water table in a small, nonpumping well.
	Pliocene	Geological epoch of the Tertiary period, starting about 12 million years ago.
	PM-10	Fine particulate matter with an aerodynamic diameter equal to or less than 10 microns.
	Point source	Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack).
	Pretreatment	Any process used to reduce a pollutant load before it enters the sewer system.

	Pretreatment regulations	National wastewater pretreatment regulations, adopted by EPA in compliance with the 1977 amendments to the Clean Water Act, which required that EPA establish pretreatment standards for existing and new industrial sources.
	Priority pollutants	A set of organic and inorganic chemicals identified by EPA as indicators of environmental contamination.
Q	Quality assurance (QA)	A system of activities whose purpose is to provide the assurance that standards of quality are attained with a stated level of confidence.
	Quality control (QC)	Procedures used to verify that prescribed standards of performance are attained.
	Quality factor	The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses (on a common scale for all ionizing radiation) the biological damage to exposed persons. Quality factor is used because some types of radiation, such as alpha particles, are biologically more damaging than others. Quality factors for alpha, beta, and gamma radiation are in the ratio 20:1:1.
	Quaternary	The geologic era encompassing the last 2–3 million years.
R	Rad	The unit of absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One rad equals 0.01 joule per kilogram, or 0.01 gray.
	Radioactive decay	The spontaneous transformation of one radionuclide into a different nuclide (which may or may not be radioactive), or de-excitation to a lower energy state of the nucleus by emission of nuclear radiation, primarily alpha or beta particles, or gamma rays (photons).
	Radioactivity	The spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.
	Radionuclide	An unstable nuclide. See nuclide and radioactivity.
	Rem	A unit of radiation dose equivalent and effective dose equivalent describing the effectiveness of a type of radiation to produce biological effects; coined from the phrase “roentgen equivalent man.” It is the product of the absorbed dose (rad), a quality factor (Q), a distribution factor, and other necessary modifying factors. One rem equals 0.01 sievert.

	Risk assessment	The use of established methods to measure the risks posed by an activity or exposure. In the present context, risk assessments evaluate: (1) the relationship between exposure to radioactive substances and the subsequent occurrence of health effects; and (2) the likelihood for that exposure to occur.
	Roentgen	A unit of measurement used to express radiation exposure in terms of the amount of ionization produced in a volume of air.
S	Sampling and Analysis Plan	A detailed document describing the procedures used to collect, handle, and analyze ground water samples. The plan details quality control measures that will be implemented to ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements.
	Sanitary waste	Most simply, waste generated by routine operations that is not regulated as hazardous or radioactive by state or federal agencies.
	Saturated zone	A subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone.
	Sensitivity	The capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte.
	Sewerage	The system of sewers.
	Sievert (Sv)	The SI unit of radiation dose equivalent and effective dose equivalent. This is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. One sievert equals 100 rem.
	Sitewide Maximally Exposed Individual (SW-MEI):	The sitewide maximally exposed individual member of the public is defined as the hypothetical person who receives, at the location of a given publicly accessible facility (such as a church, school, business, or residence), the greatest LLNL-induced effective dose equivalent (summed over all pathways) from all sources of radionuclide releases to air at a site. Doses at this receptor location caused by each emission source are summed, and yield a larger value than for the location of any other similar public facility. This individual is assumed to continuously reside at this location 24 hours per day, 365 days per year.
	Specific conductance	Measure of the ability of a material to conduct electricity. Also called conductivity.

	Superfund	The common name used for the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). California has also established a “State Superfund” under provisions of the California Hazardous Waste Control Act.
	Surface impoundment	A facility or part of a facility that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials, although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons.
T	Tritium	The radioactive isotope of hydrogen, containing one proton and two neutrons in its nucleus. It decays at a half-life of 12.3 years by emitting a low-energy beta particle.
	Transuranic waste	Material contaminated with alpha-emitting transuranium nuclides, which have an atomic number greater than 92 (e.g. ^{239}Pu), half-lives longer than 20 years, and are present in concentrations greater than 100 nCi/g of waste.
	Tukey-Kramer HSD Test	The Tukey-Kramer honestly significant difference test, a statistical technique for testing differences among group means.
U	Unsaturated zone	That portion of the subsurface in which the pores are only partially filled with water. The direction of water flow is vertical in this zone; which is also referred to as the vadose zone.
V	Vadose zone	The partially saturated or unsaturated region above the water table that does not yield water to wells.
W	Wastewater treatment system	A collection of treatment processes and facilities designed and built to reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.
	Water table	The water-level surface below the ground at which the unsaturated zone ends and the saturated zone begins. It is the level to which a well that is screened in the unconfined aquifer would fill with water.
	Weighting factor	A value used to calculate dose equivalents. It is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. The weighting factors used in this report are recommended by the International Commission on Radiological Protection (ICRP 1980).

	Wind rose	A diagram that shows the frequency and intensity of wind from different directions at a specific location.
Z	Zone 7	The common name for the Alameda County Flood Control and Water Conservation District. Zone 7 is the water management agency for the Livermore-Amador Valley with responsibility for water treatment and distribution. Zone 7 is also responsible for management of agricultural and surface water and the ground water basin.

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